

इंटरनेट

मानक

Disclosure to Promote the Right To Information

Whereas the Parliament of India has set out to provide a practical regime of right to information for citizens to secure access to information under the control of public authorities, in order to promote transparency and accountability in the working of every public authority, and whereas the attached publication of the Bureau of Indian Standards is of particular interest to the public, particularly disadvantaged communities and those engaged in the pursuit of education and knowledge, the attached public safety standard is made available to promote the timely dissemination of this information in an accurate manner to the public.

“जानने का अधिकार, जीने का अधिकार”

Mazdoor Kisan Shakti Sangathan

“The Right to Information, The Right to Live”

“पुराने को छोड़ नये के तरफ”

Jawaharlal Nehru

“Step Out From the Old to the New”

IS 15677 (2006): Metering of natural gas - Code of practice
[PGD 26: Weights and Measures]



“ज्ञान से एक नये भारत का निर्माण”

Satyanarayan Gangaram Pitroda

“Invent a New India Using Knowledge”



“ज्ञान एक ऐसा खजाना है जो कभी चुराया नहीं जा सकता है”

Bhartrhari—Nitiśatakam

“Knowledge is such a treasure which cannot be stolen”

BLANK PAGE



IS 15677 : 2006

भारतीय मानक
प्राकृतिक गैस का मापन — रीति संहिता

Indian Standard
METERING OF NATURAL GAS —
CODE OF PRACTICE

ICS 75.060; 75.180.30

© BIS 2006

BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

June 2006

Price Group 14

FOREWORD

This Code was adopted by the Bureau of Indian Standards, after the draft finalized by the Weights and Measures Sectional Committee had been approved by the Production and General Engineering Division Council.

The transportation and distribution of natural gas through cross-country pipelines are the major business of the oil companies. Similarly, the accuracy of metering and regulating of gas at different delivery points are necessary for the consumer satisfaction. Considering the measurements of all the metering and for the consumer satisfaction, Bureau of Indian Standards has formulated this Code. To formulate this Code, BIS has taken considerable assistance from major oil and gas handling organizations of India.

For further details on regulating stations for metering of Natural Gas, reference may be made to 'Code of Practice for Installation and Commissioning Natural Gas Dispatch Terminals'.

In preparing this standard considerable assistance has been derived from the following publications:

ISO 2186 : 1973	Fluid flow in closed conduits — Connections for pressure signal transmissions between primary and secondary elements
ISO 5167-2 : 2003	Measurement of fluid flow by means of pressure differential devices inserted in circular cross-section conduits running full — Part 2 : Orifice plates
ISO 5168 : 1998	Calculation of the uncertainty of a measurement of flow rate
ISO 5208 : 1993	Production pressure testing requirements
ISO 6976 : 1995	Natural gas-calculation of calorific value density, relative density and Wobbe Index
ISO 9951 : 1993	Measurement of gas flow in closed conduits-turbine meters
AGA 3	American Gas Authority Report for Orifice Plate Meter
AGA 5	American Gas Authority Report for Energy Calculation
AGA 7	American Gas Authority Report for Turbine Meter
AGA 8	American Gas Authority Report for Compressibility and Super Compressibility (NX 19) for Natural Gas and Other Hydrocarbon Gases
AGA 9	American Gas Authority Report for Ultrasonic Meters
AGA 11	American Gas Authority Report for Mass Flow Meter

CONTENTS

<i>Title</i>	<i>Page</i>
1. SCOPE	1
2. REFERENCES	1
3. ABBREVIATIONS	1
4. CLASSIFICATION	1
5. METER SELECTION	2
6. DESIGN OF METERING SYSTEM	3
 ANNEX A METERING BY ORIFICE METERS	 15
ANNEX B PERIODICAL INSPECTION CARD	18
ANNEX C PERIODICAL INSPECTION CARD	19
ANNEX D WITNESS CERTIFICATE FOR ORIFICE PLATE INSTALLATION	20
ANNEX E METERING BY TURBINE METERS	20
ANNEX F METERING BY ULTRASONIC METER	23
ANNEX G MULTIPATH ULTRASONIC METER FLOW-CALIBRATION ISSUES	31
ANNEX H ESTIMATION OF UNCERTAINTY	35
ANNEX J SECONDARY INSTRUMENTATION	37
ANNEX K GAS PROPERTIES RELATED TO METERING	39
ANNEX L CALCULATION OF CALORIFIC VALUES, DENSITY, RELATIVE DENSITY AND WOBBE INDEX FROM NATURAL GAS COMPOSITION	41
ANNEX M INSTALLATION AND COMMISSIONING	42
ANNEX N OPERATION AND MAINTENANCE	43
ANNEX P GAS ANALYSIS AND RECORDING CALORIMETERS	45
ANNEX Q SAFETY ASPECTS	47
ANNEX R AREAS OF CONCERNS OF EXISTING TERMINALS AND CORRECTIVE ACTIONS	49
ANNEX S BIBLIOGRAPHY	49

**AMENDMENT NO. 1 DECEMBER 2007
TO
IS 15677 : 2006 METERING OF NATURAL GAS —
CODE OF PRACTICE**

*(Foreword, last para, lines 10, 11, 12, 13, 14 and 15) — Substitute
'American Gas Association' for 'American gas authority'.*

(Page 28, Fig. 11) — Substitute 'REPEATABILITY' for 'REPATABILITY'.

(PG 26)

Reprography Unit, BIS, New Delhi, India

Indian Standard
METERING OF NATURAL GAS —
CODE OF PRACTICE

1 SCOPE

1.1 This Code gives guidance on the specification, design, installation, operation and maintenance of metering systems for high accuracy flow measurement.

3 ABBREVIATIONS

Speed-of-sound	SOS
Ultrasonic flow meter	USM

4.1.1 Small terminal (2 000 to 50 000 SCMD) with and without condensate/dust should have (see Fig. 1 to 4):

- a) a pre-filter/dual pre-filter with a bypass/with condensate handling and storage unit arrangement.
- b) dual hot standby PCV/SDV combination.
- c) metering by flow meters with dedicated and reliable/un-interrupted power source flow computer system.
- d) suitably sized flow control device may be provided to protect over speed of turbine/rotary piston meters.
- e) spot sampling at the trunk line with Gas chromatograph can be either online or laboratory type.
- f) flow computer may have communication port to enable hook up to SCADA system for remote monitoring.

4.1.2 Medium terminal (50 000 to 1 000 000 SCMD) with or without condensate/dust should have (see Fig. 5 and 6):

- a) a dual pre-filter with condensate handling and storage facility.
- b) dual hot standby PCV/SDV combination.
- c) dual metering lines employing flow meters.
- d) suitably sized flow control device may be

provided to protect over speed of turbine meters.

- e) spot sampling at the trunk line with Gas chromatograph can be either online or laboratory type.
- f) flow computer may have communication port to enable hook up to SCADA system for remote monitoring.

4.1.3 Large terminal (Above 1 000 000 SCMD) with or without condensate/dust should have (see Fig. 7 to 9):

- a) a dual pre-filter with automatic condensate handling and storage facility.
- b) dual hot standby PCV/SDV combination.
- c) N + 1 metering lines employing flow meters, each meter run sized for 50 percent of the terminal capacity.
- d) suitably sized flow control device may be provided to protect over speed of turbine meters.
- e) on-line Gas chromatograph/auto sampler for gas analysis.
- f) flow computer may have communication port to enable hook up to SCADA system for remote monitoring.

NOTE — SCMH is the unit instead of SCMD divided by 24 N is an integer and greater than 1.

5 METER SELECTION

COMPARISON OF SALIENT FEATURES

Factors Affecting Performance	Type of Primary Sensing Meter		
	Orifice	Turbine	Ultrasonic
Accuracy	< 1.0 percent can be achieved without flow-calibration	0.5 percent achievable with flow-calibration at working conditions	< 0.5 percent can be achieved with flow-calibration
Rangeability	3 : 1	10 : 1	50 : 1
Accommodating future demand increase	Orifice bore sizing DP range increase (limited to 10 000 mm under extreme conditions)	Additional meter runs required increase pressure	Additional meter runs required increase pressure
Installation	Long lengths of pipeline required depending on upstream fitting and Beta	Relatively short lengths required	Relatively short lengths required
Permanent pressure loss	Less than 0.05 MPa	0.01 MPa at 4 MPa	Negligible
Over-ranging of flow	Leads to buckling of orifice plates which can result in under-registration	Rotor damage premature bearing damage. However 20 percent over-ranging is permissible for short durations. Meter to run at 65 percent to 75 percent on continuous duty (OIML R 32)	No damage, loss of signal is possible

Factors affecting performance	Type of primary sensing meter		
	Orifice	Turbine	Ultrasonic
Cyclic flow variations	Generally over-registration	Appreciable over-registration	Not affected
Cyclic pressure	Resonance in impulse line can lead to large metering errors	Damage to moving parts. Over-registration possible	Not affected
Gas impurities-solids	Orifice edge erosion and debris built up at the upstream	Minimal effect on accuracy, until extensive damage to blades	Not affected
Liquids in gas	Corrosion and erosion, leading to under registering	Corrosion and rotor freezing possible damage to rotor and bearing failures	Corrosion possible
Stability	Good stability can be achieved by regular maintenance of upstream filter, orifice plate installation and calibration of DP instruments	Very good stability possible by regular lubrication of bearing and spin-time tests to check for increased friction	Very good stability, self diagnostic features available

6 DESIGN OF METERING SYSTEM

6.1 Nature of the Gas to be Metered

The gas being metered shall be clean, dry and non-corrosive.

6.2 Types of Metering

6.2.1 Orifice Meters

The specification for orifice meters and guidance on their application is given in Annex A. To achieve the stated uncertainty levels on the primary metering equipment without prior calibration in Annex H shall be followed (*see also* IS 15675).

6.2.2 Turbine Meters

Guidance on use, installation and operation of turbine meters are given in Annex E. The accuracy achieved will be dependent on the initial calibration which should be performed at working conditions (*see also* IS 15676).

6.2.3 Multi-path Ultrasonic Meters

Multi-path ultrasonic meters are relatively new. Guidance on use, installations and operation is given in Annex F. Multi-path ultrasonic meters do not need calibration but they should be calibrated before use at near working conditions. These meters have the potential for accuracy comparable to that of orifice or turbine meters, operate on fundamental physical principles and have the capacity to be self-checking (*see also* IS 15674).

6.2.4 Rotary Piston Meters

For use of rotary piston meters (*see* IS 15673).

6.2.5 Coriolis Meters

For use of coriolis meters (*see* IS 15672).

6.3 Metering Requirements

6.3.1 The nature of flow is very important for the performance of the meter. The following is desirable to achieve intended accuracy levels:

- Flow should be steady,
- Flow should be free from pulsations,
- Flow shall be parallel to the axis of the upstream pipe work, and
- There should be no swirling motion.

All pipe work fittings, for example, bends, tees, valves and regulators, will produce unstable, distorted velocity profiles. Those fittings whose cross-sectional area increases in the flow direction, for example, diffuser may generate the worst flow disturbances.

6.3.2 In orifice plate meter installations, combinations of bends in more than one plane should be avoided at the meter run inlet because they give rise to swirl. Small-scale features such as gasket protrusions or steps in the pipe may also cause significant effects on turbine and orifice meter accuracy and should be avoided.

6.3.3 To stabilize and regularize the velocity profile downstream of pipe work fittings, straight pipe lengths

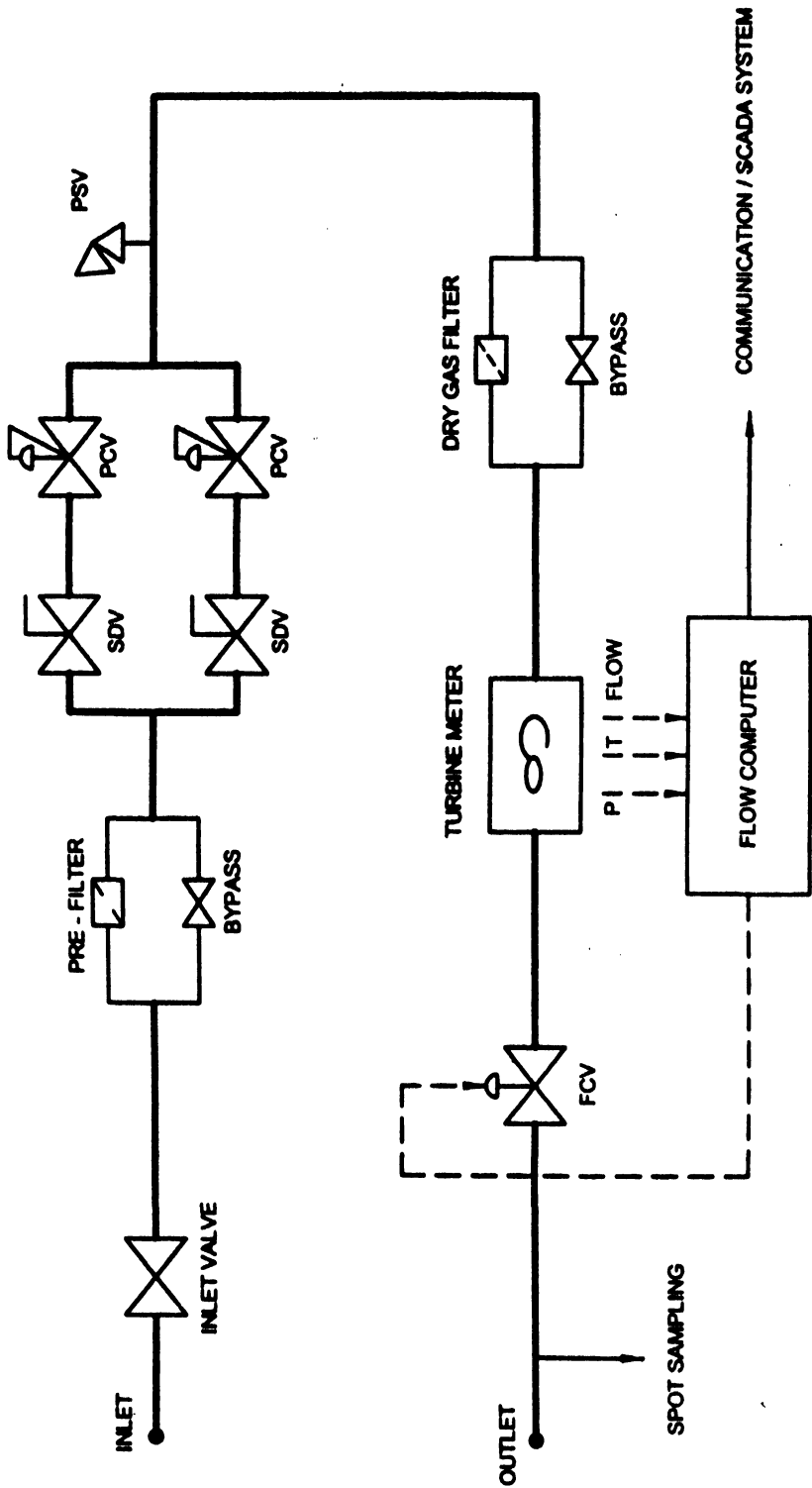


FIG. 1 INDICATIVE DIAGRAM FOR SMALL TERMINAL (WITHOUT CONDENSATE/DUST)
(2 000 SCMD to 50 000 SCMD)

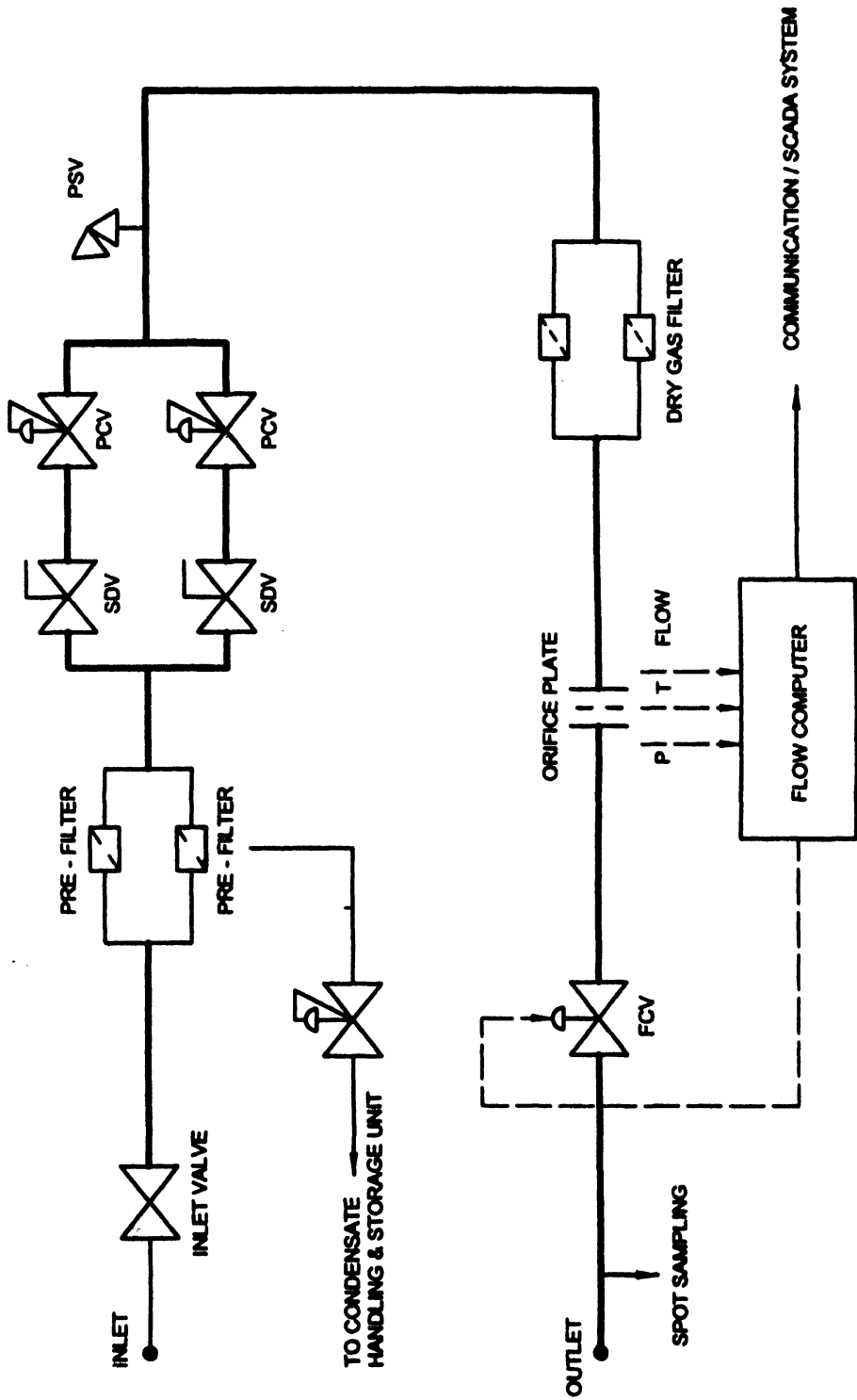


Fig. 2 INDICATIVE DIAGRAM FOR SMALL TERMINAL (WITH CONDENSATE/DUST)
(2 000 SCMD to 50 000 SCMD)

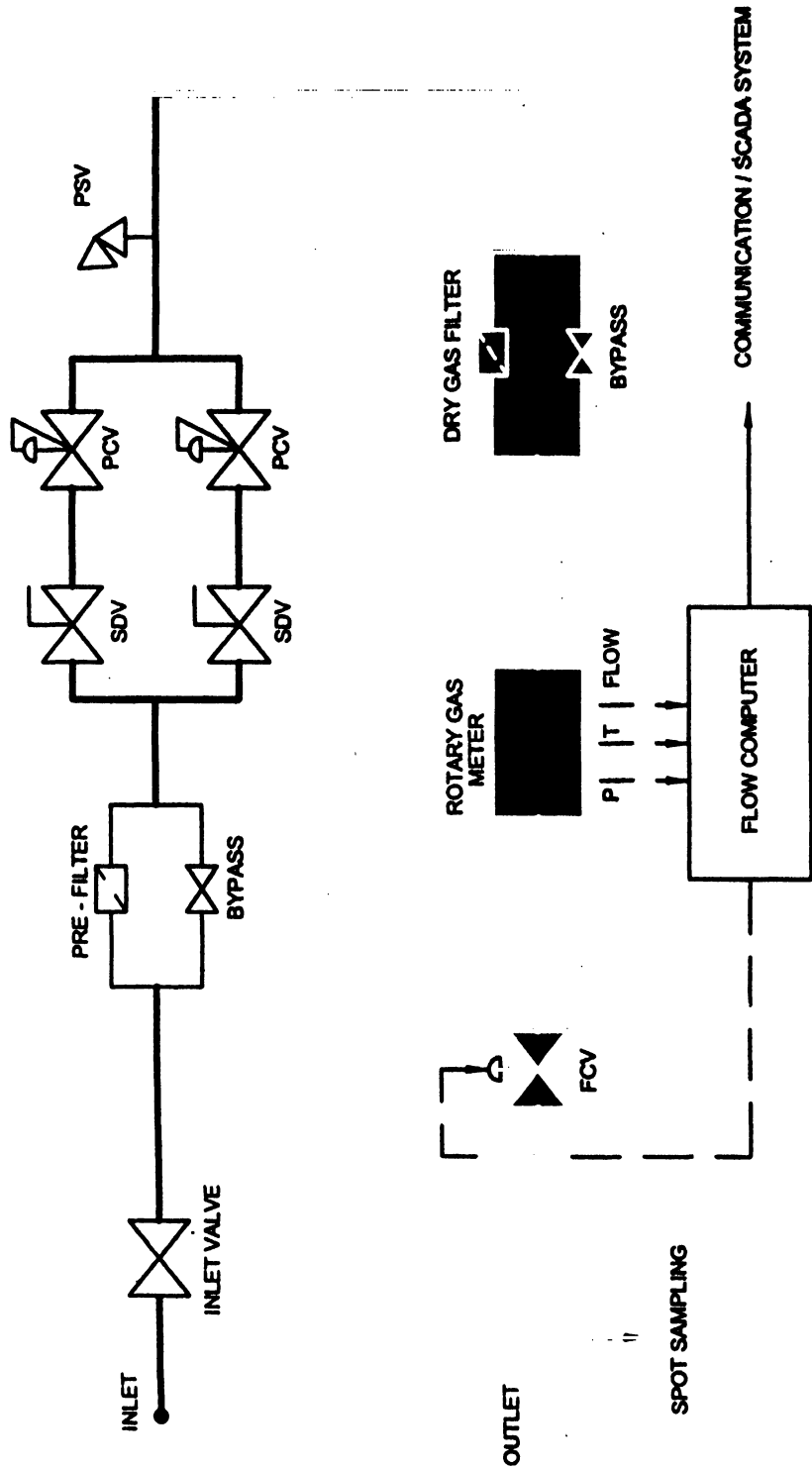


FIG. 3 INDICATIVE DIAGRAM FOR SMALL TERMINAL WITH ROTARY GAS METER
(2 000 to 50 000 SCMD)

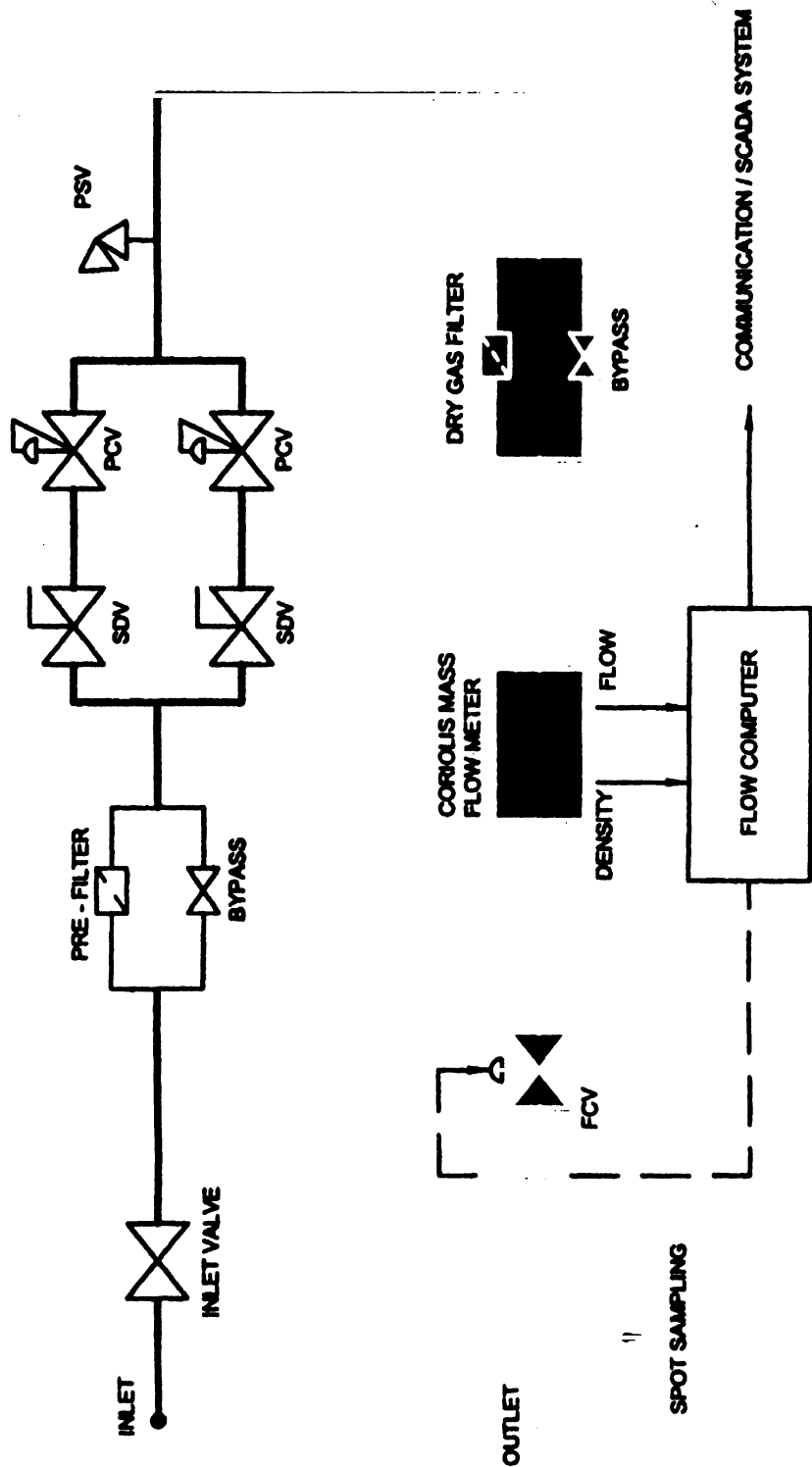


FIG. 4 INDICATIVE DIAGRAM FOR SMALL TERMINAL WITH CORIOLIS MASS FLOW METER
(2 000 to 50 000 SCMD)

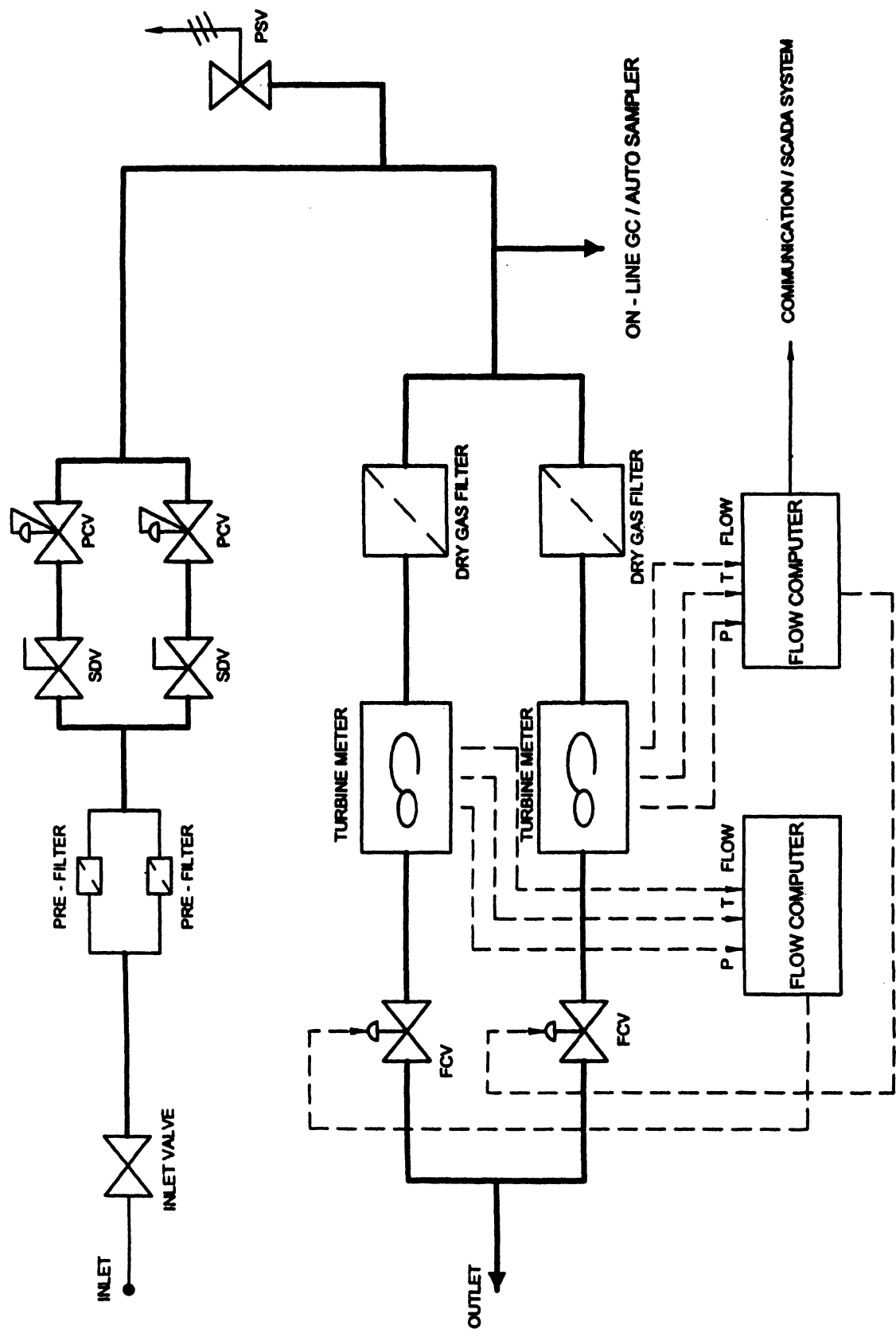


FIG. 5 INDICATIVE DIAGRAM FOR MEDIUM TERMINAL (WITHOUT CONDENSATE/DUST)
(50 000 SCMD to 1 000 000 SCMD)

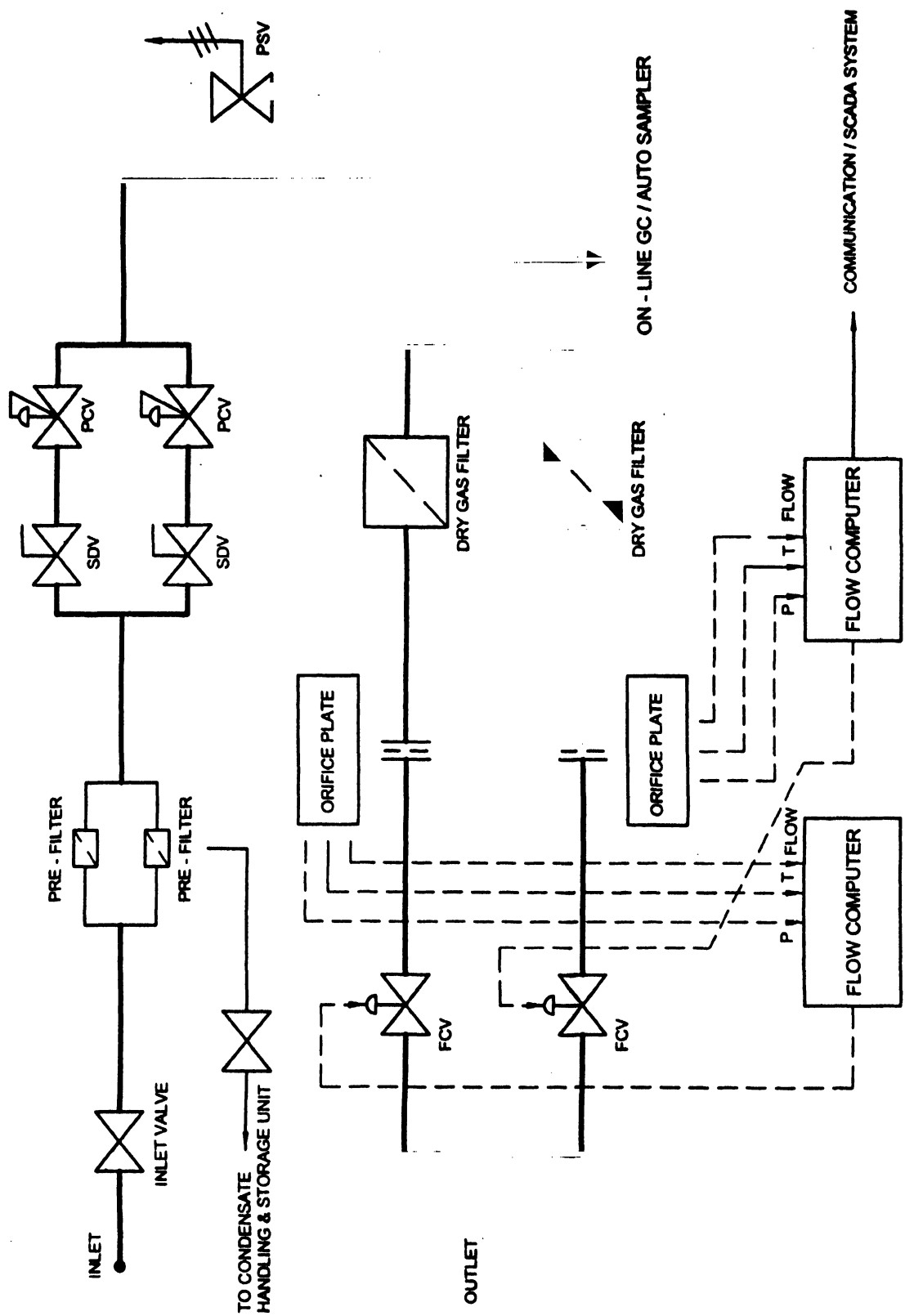


FIG. 6 INDICATIVE DIAGRAM FOR MEDIUM TERMINAL (WITH CONDENSATE/DUST)
(50 000 SCMD to 1 000 000 SCMD)

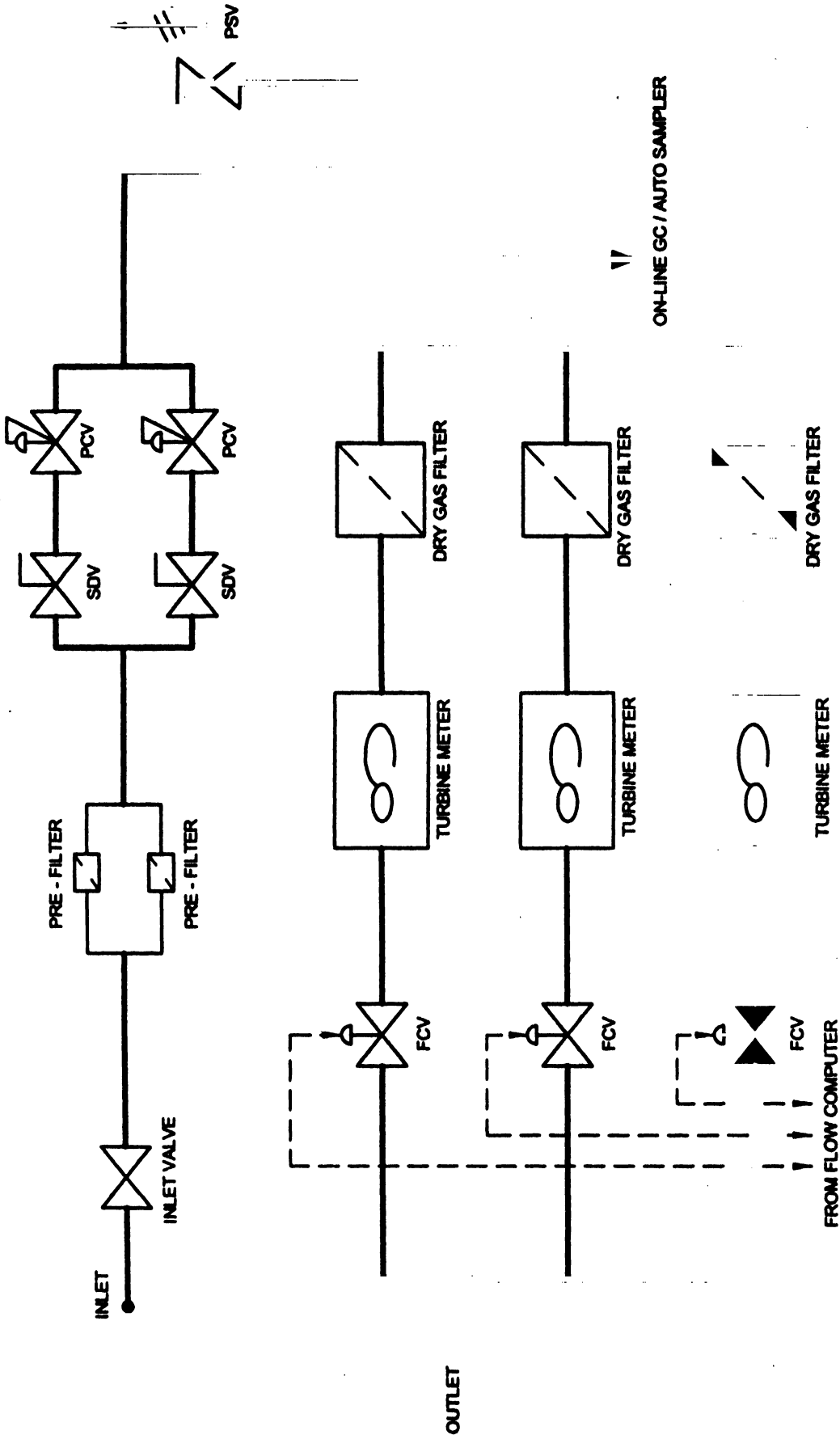


FIG. 7 INDICATIVE DIAGRAM FOR LARGE TERMINAL (WITHOUT CONDENSATE/DUST)
(MORE THAN 1 000 000 SCMD)

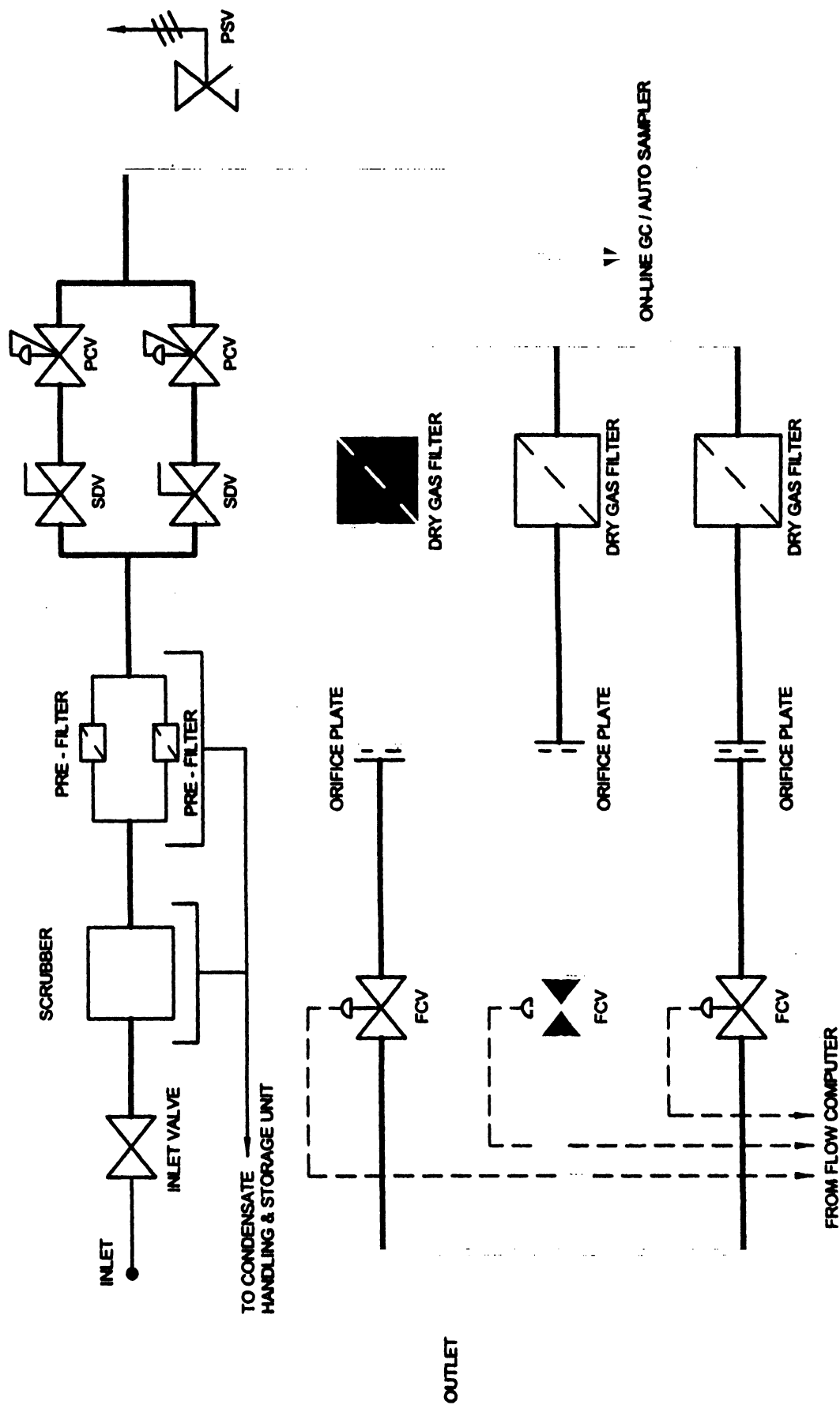


FIG. 8 INDICATIVE DIAGRAM FOR LARGE TERMINAL (WITH CONDENSATE/DUST)
(MORE THAN 1 000 000 SCMD)

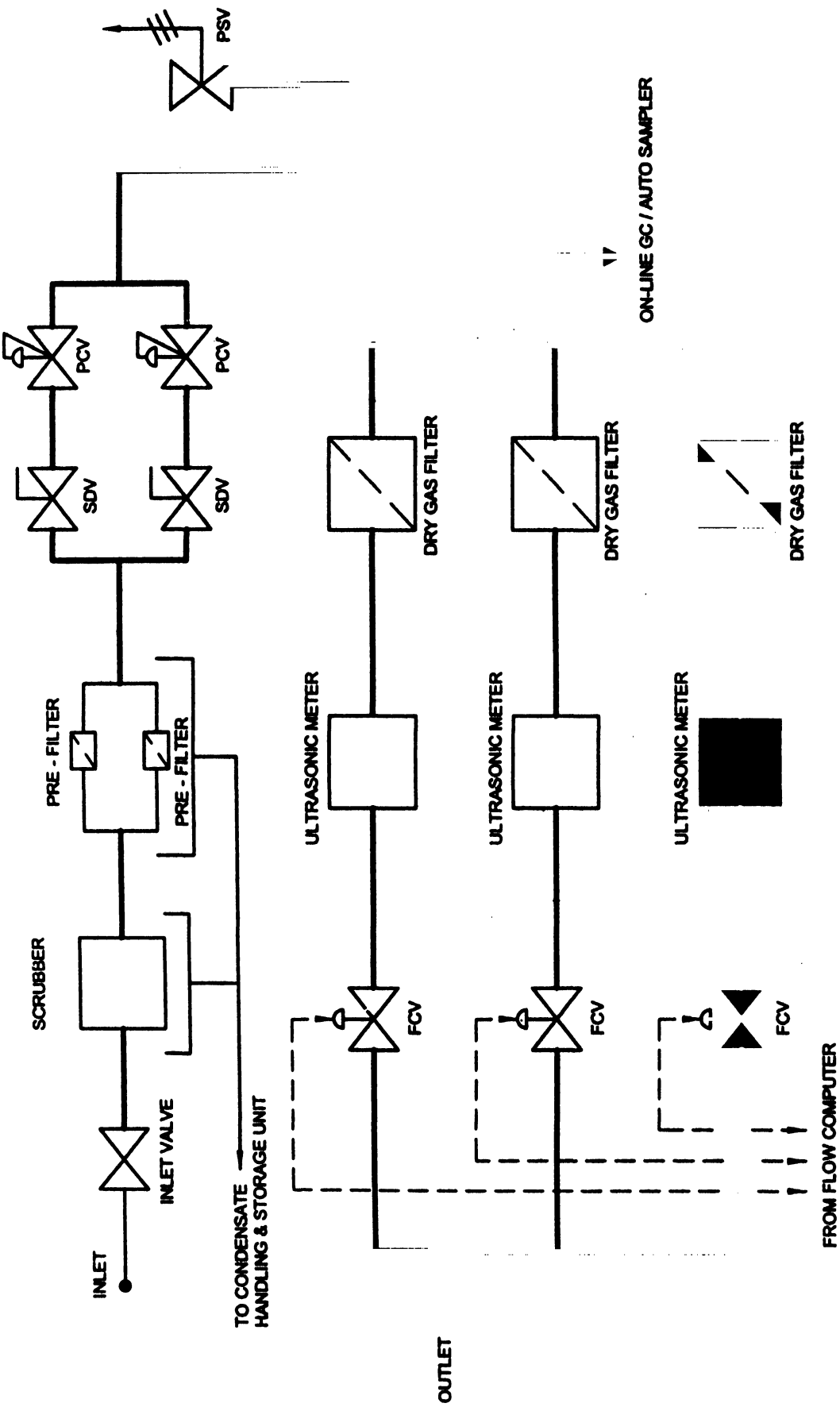


Fig. 9 INDICATIVE DIAGRAM FOR LARGE TERMINAL (WITH CONDENSATE/DUST)
(MORE THAN 1 000 000 SCMD)

should be included in which flow conditioners may, additionally, be used.

6.4 Terminology

For the purpose of this standard, the following definitions shall apply.

6.4.1 Pulsations — Optimum metering accuracy requires that the gas flow shall be free of pulsations. Large metering errors may occur if the pulsation level at the meter is excessive and has not been limited, for example, by a pulsation damper.

Compressors located upstream or downstream of a meter may cause pulsations at the meter and, under certain operating conditions, pipe fitting and control equipment may also produce unsteady flow.

Based upon the present state of knowledge of pulsation effects, the installation of pulsation dampers should be considered when the pulsation frequency is higher than 1 cycle/min and the pulsation amplitude of either the static pressure exceed ± 5 percent of the absolute static pressure or the flow rate exceeds ± 10 percent of the mean flow value.

6.4.2 Velocity — The velocity profile at the approach to a meter may be critical to meter performance. In general, orifice plate meters require a more developed profile than turbine or ultrasonic meters. The gas velocity in pipe work associated with a flow measurement system should not exceed 30 ms^{-1} . The mean velocity in headers, supplying parallel meter streams, shall be limited to 20 ms^{-1} .

6.4.3 Flow Rate — To accommodate future growth, and in particular for turbine meters consideration shall be given to using a smaller diameter tube in a run designed for a larger diameter meter tube. In the case of orifice plate meters, it would generally be the case that a full size pipe would be used and the plate would be changed.

6.5 Installations (see Annex M)

6.5.1 Mechanical Aspects

In general, meters shall be installed upstream of any heater and pressure/volumetric regulation equipment to avoid swirls and ensure fully developed flow profile. However in certain metering installations, particularly where station inlet pressures fluctuate, it may be necessary to install the meter downstream of the heater and regulators. This may degrade the meter performance if sufficient care is not taken in ensuring fully developed flow profile.

6.5.2 Consideration shall be given to fitting an additional line to all meter installations with a single working meter. The additional line may be designed

to allow a future second metering stream to be installed under operating conditions that is to be double-valved. For custody transfer metering, any lines shall be securely and demonstrably closed.

6.5.3 The preparation of the design and general arrangement of a measurement system should take into account the overall pressure drop through the system.

6.5.4 Meters shall not be fixed at low points in the pipe work system. All low points shall be fitted with drains. Provision shall be made for isolation, safe venting, draining and purging of the metering system. Any section of the pipe or fittings between two valves should incorporate a minimum of one vent and one drain. The vent shall be sized to permit reasonable venting times without causing excessive flows through the meter or excessive cooling.

6.5.5 Special consideration shall be given to adequate lighting of areas where metering and instrumentation are located.

6.6 Important Guidelines for Different Component Installation and Commissioning

6.6.1 Valves for gas metering lines shall be full bore ball valves upstream, of the meter. If the gas is dirty, ball valves are not ideal as grit/dirt can damage the seats and/or the ball. In these conditions, a gate valve or a twin seal valve/block and bleed valve may be used.

6.6.2 To take care of passing valves, double valving shall be employed both upstream and downstream of the meter with the ability to vent the cavity between the two valves.

6.6.3 Forced lubricated plug valves should not be used as grease may ingress into the line and deposit on the meter and in the meter tube.

6.6.4 All valves should have position indicators to show clearly whether the valves are open or closed.

6.6.5 All isolating valves shall be capable of being locked in the open or closed position to prevent unauthorized operation.

6.7 Pipe Work Requirements

Pipe work immediately adjacent to meters and orifice plate carriers shall be adequately supported and also protected by a non-metallic sleeve. Care shall be taken to ensure that there is no transfer of loading from the pipe work to the meter or carrier that may create unacceptable stresses in the meter or carrier body and flanges.

6.8 Gas Cleaning System

6.8.1 The gas shall be filtered to a level of 5 microns at 95 percent efficiency.

6.8.2 Facilities for gas cleaning at the immediate inlet to flow measurement system should include, as appropriate, one of the following:

- a) Fine filter, or
- b) Scrubber(s) followed by fine filters, or
- c) Combined scrubber-filter unit(s).

It is desirable to install two or more streams with suitable valving and connections to permit the main filter to be maintained.

6.8.3 If possible, scrubbers and filters shall be commissioned before the meters are brought on stream. This will allow removal of construction deposits which may be lying in the system, before the meter is commissioned. If this is not possible, regular inspection of the filtering section shall be carried out during the first weeks of operation. It is important to guard against bursting of filters by monitoring the differential pressure across the filter. In any case, the filtering media should never be removed altogether.

6.9 Straight Pipe Lengths

The straight length requirements both upstream and downstream of the meter shall be adhered to, if the minimum uncertainty is to be achieved. The straight length requirements imply that the pipe shall be circular, of an acceptable smoothness and free from protrusions from sources such as weld penetration or gaskets.

These requirements are specified for orifice plate meters, turbine meters, ultrasonic meters and for coriolis meters.

6.10 Calculation

An appropriately configured computer shall be chosen to meet the required overall uncertainty.

It currently available flow computers do not add significantly to the uncertainty of a flow measurement calculation and are carrying out the full calculation of the various flow quantities. Any approximation to these quantities may lead to loss of accuracy. Possible approximations that computers may use could affect the estimation of density (*via* compressibility), orifice discharge coefficient, orifice expansibility and turbine meter error curve. Complete specifications for the flow computer are dealt with somewhere else in this standard.

6.11 Inspection

A full metrological inspection shall be carried out before use if orifice meters are to be used without a flow calibration. Traceable instrumentation and specialist equipment for the measurement of orifice

plate square edge shall be used. Full documentation of these inspections is required and shall be retained.

6.12 If the gas is clean, dry (or single phase) and non-corrosive, then orifice plate or turbine or coriolis or ultrasonic meters may be chosen. The meter chosen should perform satisfactorily within the limits of their specification.

If the gas fails to meet these criteria, it shall be accepted that some degradation of accuracy may occur. It is not possible to accurately predict the uncertainty on account of above.

The presence of dirt may damage the square edge of an orifice plate and substantial amounts of liquid may alter the discharge coefficient.

Turbine meter bearings may be affected by dirt and the presence of any liquid may also affect its accuracy. All meters may be affected by corrosive components in the gas. Great caution needs to be exercised in claiming specific levels of accuracy under such conditions.

Reference shall be made for guidance on the factors affecting the choice of the primary metering equipment.

6.13 Installation Defects

6.13.1 Any electrical equipment associated with a meter installation shall be designed, constructed and installed in accordance with IS 2148.

The hazardous area classification as given below, of the meter installation shall be determined by means of a full hazard assessment:

- a) **Zone 0:** An area in which an explosive gas/air mixture is continuously present or present for long periods.
- b) **Zone 1:** An area in which an explosive gas/air mixture is not likely to occur in normal operation.
- c) **Zone 2:** An area in which an explosive gas/air mixture is not likely to occur in normal operation and, if it occurs, it will exist only for a short time.

By implication, an area which is not classified as Zone 0, Zone 1 or Zone 2 is deemed to be non-hazardous or a safe area.

Even in safe area, care shall be taken of any constraints imposed by any adjacent hazardous area.

6.13.2 Where a meter is in a hazardous area, electrical equipment, for example, lighting and instrumentation shall be appropriately certified for safe use in the designated zone. If the required equipment is not certified or suitable for use in the designated area, it shall be fitted in a safe area or in a separate

compartment having gas-tight walls and outside access only to a safe area.

6.13.3 Any electrical device and associated circuits, for example, a pulse transmitter, mounted in or on a

6.13.7 Intrinsically safe circuits shall not be intermixed with non-intrinsically safe circuits in the same multi-core cable.

6.14 Safety

area as a minimum requirement.

6.13.4 Metering installation may incorporate a variety of electrical supplies, both ac and dc. Power cables (220 V and above) for lighting and motors, etc, shall be separated by at least 0.3 m from instrument cables to minimize pick-up in instrument circuits.

6.13.5 Instrument and control cabling shall be a screened cable with twisted conductors to be used to avoid pick-up. Cable armouring and screens shall be correctly earthed in accordance with the system and certificate requirements. All metering equipment's shall be immune to EMI/RFI interferences.

6.13.6 Cable screens and armour shall be insulated from the pipe work, especially where cathodic protection systems exist. Where intrinsically safe systems are employed, the cable parameter shall conform to the system certificate.

The whole of the electrical installation shall be earthed. Where sites have a cathodic protection, specialist advice may be required.

6.15 Lightning Protection

6.15.1 If a nearby lightning strike could cause damage to equipment and render it unsafe in a manner that is not obvious, the installation shall be protected against static discharge.

If there are reasonable grounds to believe that there is possibility of hidden, unsafe failures due to a lightning strike then suitable protection shall be provided in the form of either:

- a) A lightning barrier plus a certified protective device, or
- b) A lightning barrier suitable for Zone 2 hazardous area apparatus, as appropriate.

ANNEX A

(Clause 6.2.1)

METERING BY ORIFICE METERS

A-1 INTRODUCTION

The orifice meter determines flow by means of a measurement of the differential pressure. The differential pressure is induced by the flow of gas through a thin plate with a sharp square edge opening which is circular and concentric with the pipeline. The flow rate is related to the differential pressure, the gas

- a) Orifice plate,
- b) Orifice plate holder including the pressure tap holes, and
- c) Upstream and downstream pipe work.

A-2.1.1 The gas flow approaching the orifice plate shall be free from swirl, sub-sonic and have a fully developed flow profile. It should also be free from

For high pressure gas metering, the flange tapping configuration should only be employed.

A-4 DESIGN RESTRICTIONS

A-4.1 When metering high pressure gas to the accuracy required for custody transfer, the additional restrictions on the design shall be complied with.

A-4.2 Concentricity, perpendicularity and the scaling of the orifice plate in the meter tube should meet the requirements of the standard and this is, generally, achieved by means of an orifice fitting.

A-4.3 Dual chamber fittings (orifice) allow the plate to be removed while under pressure and these devices may be useful for regular inspection of the orifice plate. However, it shall be noted that such devices do not, normally, provide double isolation from line pressure which is a common requirement at high pressures.

A-4.4 Beta Range Restrictions

The orifice plate beta shall be within the limits of 0.2 to 0.75, in order to minimize the basic flow coefficient to an uncertainty of 0.6 percent it shall be within the limit of 0.3 to 0.6.

Increasing the beta from 0.6 to 0.75 enables 95 percent more flow through the meter. However, the uncertainty may increase from 0.6 percent to 0.75 percent if the same concentricity of the orifice bore to the pipe diameter is maintained.

The lower restriction of 0.2 limits the minimum flow.

A-4.5 Reynolds Number Restrictions

The minimum Reynolds number limitation is given in AGA 3 for flange tapplings and D and D/2 tapplings.

A-4.6 Additional Metering Guidelines for High Accuracy

The following criteria shall be achieved:

- a) The meter tube is designed and constructed to achieve the minimum uncertainty.
- b) The maximum differential pressure does not exceed 2 500 mm WC. However, a higher value may be used provided the following three points relating to orifice plate flatness are achieved.
- c) The elastic deformation of the orifice plate is less than 1 percent at the maximum differential pressure used.
- d) The uncertainty caused by elastic deformation of the orifice plate is less than 0.1 percent.
- e) The location of the orifice pressure tap holes relative to the upstream edge of the orifice bore remains within the specified tolerance

for the complete range of differential pressure (see IS 15675).

A-5 PIPING LAYOUT

To design an orifice metering system there may be a number of options available based on the maximum and minimum beta used, the upstream piping configuration, the gas properties and the temperature and pressure of the gas being metered. In addition, for large gas metering station, the decision is, generally, taken to have a spare meter run to permit maintenance/removal of an orifice plate/inspection/check calibration while the remaining runs operate at maximum capacity. A further option for a metering station which could exceed the maximum flow rate may be to use a dual chamber orifice fitting and insert a high beta plate during the period of high flow.

From the calculation, it is possible to determine the inside diameter of the orifice meter run and the number of meter tubes to be used. Orifice meters with a single differential pressure transducer and a single plate have a restricted turn-down ratio of typically 3 : 1.

The use of techniques such as stacked differential pressure transducer or auto-rearranging (Smart) transducer, makes it possible to increase the turn-down ratio. Different ratio plates can be used to increase the turn-down ratio for an individual run and the overall installation turn-down may be extended still further by utilizing multiple meter runs.

To achieve the minimum uncertainty value, differential pressure transducers shall be operated towards their maximum span. Under no circumstances DP less than 20 percent of the maximum shall be considered for custody metering.

Having determined the diameter and number of meter runs, the upstream and downstream lengths of pipes shall be determined by reference to meter selection as above which gives the upstream pipe work configuration

Good metering practice should include upstream straight lengths or flow conditioners in accordance with AGA 3, to reduce swirl and generate a developed velocity profile.

As most pipe work prior to metering is complex, there is high probability of swirl and asymmetric flow in the metering streams.

A-6 MATERIALS

The materials employed for gas metering installation shall be capable of withstanding the gas composition under all conditions that may be experienced over the lifetime of the metering.

Any meter tube pipe not exceeding 600 mm diameter shall be seamless wherever possible. Above 600 mm, longitudinally S.A.W. (submerged arc welded) pipe shall be used.

The pipe shall be inspected internally to ensure that it complies with the dimensional and surface finish tolerances specified in ISO 5167.

The flanges in the vicinity of the orifice plate shall be match-bored to the pipe and also dwelled/retained in such a manner that there is no internal step in the meter tube.

On orifice fittings, the internal diameter, surface finish, concentricity and position and condition of the pressure tap holes shall be carefully manufactured and inspected to ISO 5167 or an equivalent standard.

The orifice fittings should be generally, cast.

The orifice plate shall be manufactured from stainless steel plate. The petrology of the plate shall meet the requirements of ISO 5167.

A-7 CALIBRATIONS AND TESTING (see Fig. 10)

The orifice meter tube shall be checked and recorded for conformity to ISO 5167 with particular care being taken in the 2D upstream and downstream of the orifice plate.

The orifice plate should also be thoroughly checked. Annexes B, C and D give the data sheets used to record the results of periodic inspection and witness of installation. For custody transfer metering, the plates shall be certified by an independent authority.

In addition to checking the meter tube and plate assembly, instrumentation associated with orifice metering, such as the differential pressure/pressure transmitter, temperature, density/GC units and the flow computers shall be calibrated.

All measuring instruments used for these calibration checks should have traceability to national/international primary standards.

Orifice metering has a distinct advantage over most other forms of metering with respect to calibration as simple meteorology can be used to check that the meter conformance to the standard ISO 5167. An additional uncertainty of 0.5 percent to the flow coefficient has to be added if shorter upstream lengths are adopted.

If an uncertainty better than 0.6 percent in the basic discharge coefficient is essential, then the unit shall be flow tested over the appropriate range of Reynolds numbers in a calibration laboratory. All the associated upstream and downstream piping and instrumentation should be used during the test to give a precise value

for the unit uncertainty better than 0.5 percent may not be achieved.

A-8 PERFORMANCE OF ORIFICE METERS

Temperature shall be measured downstream of the orifice up to and including 5D.

For higher accuracy. The temperature at the upstream pressure taping is required for the correction of orifice and pipe dimensions and in the calculation of density if it is not directly measured.

For high accuracy metering applications. A temperature gradient across the primary device shall be considered and an appropriate correction applied.

In an orifice metering device. The orifice bore required for optimum metering shall be calculated. This is an iterative calculation since the diameter is related to the beta which is, in turn, a function of the discharge coefficient.

To ensure the velocity flow profile at the orifice plate is fully developed and free from swirl, the required upstream straight lengths of piping should conform to AGA 3. These lengths are given in terms of multiples of D and, consequently. The larger the diameter of the tubes chosen the longer the metering station will be. Similarly, the larger the beta the longer is the meter tubes.

The meter design shall be based on the largest expected beta to be used in service.

A-9 INSTALLATION

To ensure that calibrated meter tubes are not adversely affected by the installation, they shall be installed in such a manner that:

- a) There is no ingress of dirt or grit into interior of the tube,
- b) There is no step or gasket protrusion between flanges,
- c) The position of the valves is accurately known and there is never a time when metering is taking place with a partially opened valve,
- d) They are well supported and the pipe work remains straight, and
- e) Precautions are taken to ensure that no pulsations from upstream or downstream compressor are transmitted to the meters.

The following precautions shall be taken for installation of orifice plate:

- a) The plate should not be installed until the line has been flushed out,
- b) The plate should be protected from surface or edge damage during handling,

- c) The plate should be inserted with the sharp edge facing upstream and the bevel down stream,
- d) The standard should be for a sharp square edge orifice, and
- e) The orifice plate should be checked in a routine manner to assess any deterioration.

If wet gas or dirt is present, the orifice should, preferably, be installed in a vertical line. If the meter has to be installed in a horizontal line, the meter line shall be inclined to a drain point to stop built up of water or dirt against the plate which give inaccurate results.

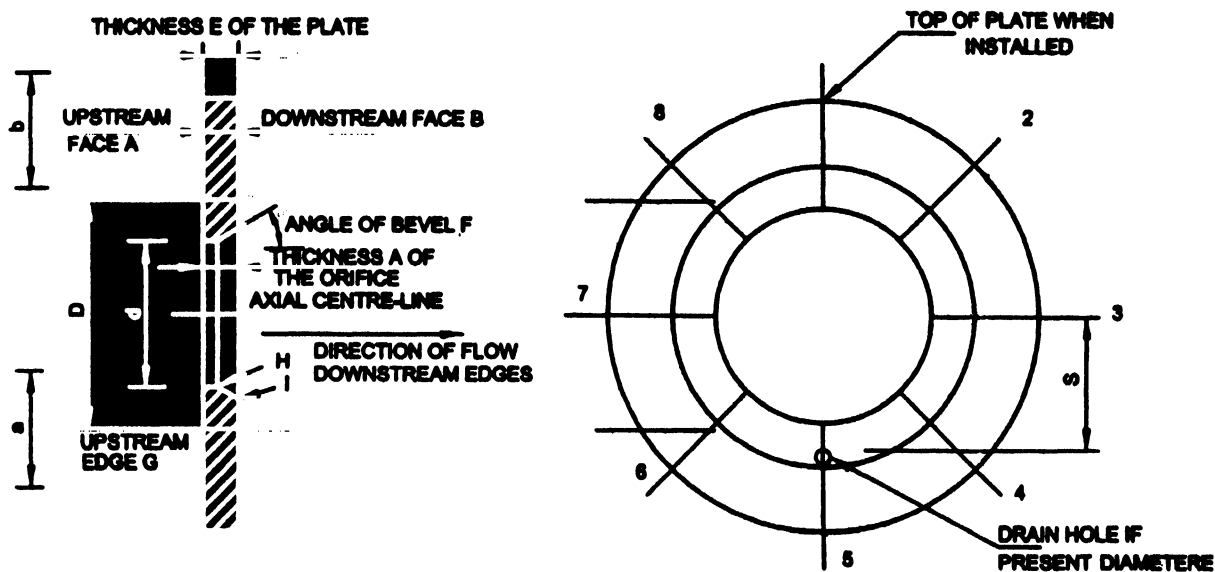


FIG. 10 ORIFICE PLATE

ANNEX B
(Clause A-7)

PERIODICAL INSPECTION CARD

Station: Certificate No.:

Flow range: Date:

Register No.:

Carrier type:

Manufacturer of plate (if applicable):

Manufacturer's serial No. of plate (if applicable):

Identification Tag:

Plate outside diameter	A = ... mm
Pipe internal diameter	D = ... mm
Orifice bore diameter (specified)	= mm
Orifice bore diameter (measured)	d = ... mm
Drain hole diameter	c = ... mm
Ambient temperature	t = ... °C

Sl No.	Requirement	Acceptable	Unacceptable
i)	Orifice bored		
ii)	Flatness of upstream face, <i>A</i>		
iii)	Smoothness of upstream face, <i>A</i>		
iv)	Plate thickness, <i>E</i> and downstream face, <i>B</i>		
v)	Edge thickness, <i>E</i>		
vi)	Angle at bevel, <i>F</i>		
vii)	Upstream edge, <i>G</i> sharpness		
viii)	Diameter of orifice, <i>d</i>		
ix)	Drain hole diameter, <i>c</i>		

Inspected by:

Certified by:

Date:

ANNEX C
(Clause A-7)
PERIODICAL INSPECTION CARD

Certificate No.:

Owner of plate:

Plate identification No.:

Station:

1. Pipe and Plate Dimensions

Specified bore diameter, *d* = Pipe internal diameter, *D* (mean) =
Measured bore diameter, *d* (mean) = Temperature when measure =

2. Measurement Stations

ANNEX D
(Clause A-7)

WITNESS CERTIFICATE FOR ORIFICE PLATE INSTALLATION

Station:
Flow range:
Meter tube serial No.:
Station tube No. (multi-tube stations only):
Register No.:
Serial No. of orifice plate certificate:
Orifice bore diameter (specified) = ... mm
Orifice bore diameter (measured) = ... mm
Drain hole diameter = ... mm
Ambient temperature = ... °C
Flatness : Satisfactory/Unsatisfactory
Condition of plate on arrival : Undamaged/Damaged
New identity tag fitted : Yes/No
This is to certify that :
a) The above described orifice plate was dimensionally checked, visually inspected and correctly fitted to the orifice at the above station.
b) There are no obvious defects in the carrier or pipework.
Date.....and witnessed by.....on behalf of
.....and.....on behalf of

ANNEX E
(Clause 6.2.2)

METERING BY TURBINE METERS

E-1 INTRODUCTION

A turbine meter is a flow measuring device in which the dynamic forces of the flowing fluid cause the turbine wheel to rotate with a speed approximately proportional to the rate of volume flow. The number of revolutions of the turbine wheel is the basis for the indication of the volume passed through the meter.

A second turbine wheel may be included in the mechanism, designed to rotate at a significantly slower speed than the first due to the difference in blade angles of the two rotors. A change in rotational speed between the two rotors for a given fluid velocity will indicate a

shift in calibration conditions, for example, a change in bearing friction, flow pulsations or a change in flow profile.

E-2 CONSTRUCTION

Meters shall be designed and manufactured in accordance with IS 15676.

E-3 MATERIALS

The meter body and the internal mechanism shall be manufactured by materials suited for the service conditions and resistant to attack by the gas which the meter is to handle. Exterior surfaces of the meter shall be protected as necessary against corrosion.

Where meters incorporate removable meter internals, flow calibration at actual conditions shall be done even if pre-calibrated internals are used.

E-4 METER ELEMENTS

E-4.1 Body Shell

The meter body shell and all other parts comprising the gas containing structure of the meter shall be constructed of suitable materials and designed to handle the pressures and temperatures for which they are rated.

The length of the meter between the ends of its inlet and outlet connections shall be equal to or less than 5 times the nominal connection size (DN). For interchangeability, a length or 3 times the nominal connection diameter is preferred.

The inlet and outlet connections of the meter should conform to recognized standards.

E-4.2 Pressure Tap Dimension

Circular taps should have a minimum bore diameter of 3 mm and maximum bore not greater than 12 mm.

The direction of flow at the inlet of the meter shall be clearly and permanently marked.

E-5 MARKING

The following minimum information shall be marked on the meters:

- Manufacture's name or trade-mark,
- Serial number,
- Maximum allowable operating pressure, and
- Flow range.

E-6 PERFORMANCE

E-6.1 Accuracy

Maximum acceptable error shall be ± 1 percent between q_{vMax} and $0.2 q_{vMax}$, and 2 percent between q_{vMin} and $0.2 q_{vMax}$.

E-6.2 Flow Rates

The maximum and minimum flow rates shall be specified for the gas densities for which the meter will operate, within the specification of meter performance.

Under normal circumstances, the rated maximum flow rate should never be exceeded. The rangeability of gas turbine meters should extend with an increase in metering pressure, due to greater kinetic energy being available. The range ability at the working conditions can be defined by the following equation:

$$R_w = \frac{R_c (\rho_w)^{0.5}}{(\rho_c)^{0.5}}$$

where

- R_w = rangeability at working conditions,
 R_c = rangeability at calibration conditions,
 ρ_w = gas density at working conditions, and
 ρ_c = gas density at calibration conditions.

The increase in rangeability of gas turbine meters with increase in pressure is caused by a reduction in the minimum flow rate q_{vMin} and not an increase in maximum flow rate q_{vMax} .

E-6.2.1 An individual calibration of each meter shall be made. The results of this calibration shall be available on request together with a statement of conditions under which the calibration took place.

E-6.2.2 Calibration Data

The calibration data provided shall include:

- error at q_{vMin} and all the following flow rates that are above q_{vMin} such as 0.1, 0.25, 0.4 and 0.7 of q_{vMax} and q_{vMax} ,
- name and location of the calibration facility,
- estimated uncertainty of the method, and
- nature and conditions (pressure and temperature) of the test gas.

E-6.2.3 The meter should be calibrated at conditions as close as possible to the conditions under which the meter is to operate, together with the specific lengths of upstream and downstream pipe work, and include any flow conditioning devices.

The facility at which the calibration is carried out shall be traceable directly to the primary national standards of mass, length and temperature.

E-6.2.4 The performance of the meter should not be adversely influenced by the installation conditions of the test facility.

E-6.3 Overloading

The meter shall be designed to be capable of, occasionally, running 20 percent above the maximum flow rate at working conditions for a period of 30 min without damage or affecting the error curve of the meter.

E-6.4 Pressure Range

The gas pressure range, over which the meter is designed to perform within standard performance specification, shall be stated.

E-6.5 Temperature Range

The gas and ambient temperature range, over which the meter is designed to perform within standard performance specification, shall be stated.

E-6.6 Readout and Output

E-6.6.1 General

The meter shall be provided with an output which may consist of a mechanical and/or electrical counter totalizing the throughout of the meter and/or an electrical pulse rate signal and/or a rotating shaft the speed of which represents the flow rate through the meter.

E-6.6.2 Counters

The number of digits in a counter shall be such that it shall show, to within one unit of the last digit, a throughout equal to at least 10 000 h of operation at the maximum flow rate.

Any counter should indicate the throughout of the meter in SI units. The counter should clearly and unambiguously state what the counter indicates and its resolution.

On a mechanical or electronic counter, the numerals of the counter shall be a minimum of 4 mm high and 2.5 mm wide. The change of numerals shall be such that the advance of one figure at any point of the counter must be completed which the last figure of the next lowest range describes the last tenth of its course.

When the only output of the meter is a mechanical counter, the readout should enable the meter to be calibrated with the required accuracy at the minimum flow rate in a reasonably short time. The smallest division of the least significant digit of the counter or test element should, therefore, be smaller than the minimum hourly flow rate divided by 400.

Provision shall be made for covering and sealing the free ends on any output shafts when they are not being use. The value per revolution of an output shaft, expressed as 1 tr = ... m³, (that is, 1 rev of the shaft equals or approximates to 'N' m³) and the direction of rotation and maximum allowable torque shall be marked on that shaft or an adjacent point on the meter.

The number of electrical pulses, per m³ indicated by the counter, shall be stated on the meter. The number of pulses representing a cubic metre (that is, meter factor) on meters without mechanical indexes shall be defined for the maximum flow rates. The equation used to calculate the flow rate using pulses and meter factor (*K*) is as follows:

$$q_v = \frac{\text{pulses}}{K \times t}$$

E-6.7 Installation

E-6.7.1 General

Turbine meters shall be operated within the specified

flow range and operating conditions to ensure the desired accuracy and normal life. The turbine meter shall be installed in accordance with the manufacturer's recommendations.

Premature wear and damage to turbine wheel may be caused by over speeding, pulsating flow and pipeline debris.

E-6.7.2 Pipe Lengths

Although the accuracy of gas turbine meters is not as sensitive to flow disturbances caused by upstream fittings as orifice plate meters, care shall be taken to ensure the flow velocity profile presented to the meter inlet is free from swirl and reasonably well developed. While most turbine meters have integral straightening vanes in the meter inlet, an additional flow conditioner upstream of the meter, is recommended for high asymmetric velocity profiles shall be avoided particularly upstream of the meter.

The type and position of any flow straightening device and the upstream and downstream straight pipe lengths should conform to those recommended by the manufacturer.

The effect of flow disturbances on measurement accuracy is dependent on the meter design.

The recommended pipe lengths shall be regarded as minimum.

E-6.7.3 Pulsation Effects on Accuracy

Turbine meters should not be used to measure flows that are rapidly pulsating since they may invariable overestimate the flow of gas. For example, a flow rate which varies sinusoidally by +20 percent about the mean flow rate could cause a turbine meter to overestimates the flow by up to 2 percent. Large pulsations in flow or pressure shall be avoided as they can cause premature failure of the meter mechanism.

E-6.7.4 Filters and Strainers

Strainers shall be used when the presence of damaging materials in the gas stream can be anticipated.

Foreign substances in a pipeline can cause serious damage to turbine meters. Strainers shall be sized so that at maximum flow there is a low pressure drop and shall be installed so that there is no flow distortion. For the maximum degree of meter protection, a dry-type or separator-type filter shall be installed upstream of the meter.

It is recommended that the differential pressure across the filter be monitored to maintain it in good condition and thus prevent, flow distortion caused by the build up of pipeline debris.

E-6.7.5 Meter Bypass

The provision of a valved bypass around the meter if an interruption of the gas flow during meter maintenance etc should not be accepted.

E-7 MAINTENANCE AND INSPECTION

E-7.1 An adequate frequency of inspection and good maintenance practice shall be followed to maximize turbine meter accuracy.

The time between meter inspection periods is dependent on the gas condition and meter performance.

Meters used in dirty gas applications will require more frequent attention than those with clean gas. Where oiling points are provided, the manufacturers' recommendations regarding frequency of oiling,

at lower flow rates, the performance of the bearings shall be monitored. Turbine meter bearings shall be always purchased from OEM. Indigenization shall be avoided.

Degradation of bearings and increased friction will cause the meter to under-register particularly at lower flow rates.

The condition of the bearings shall be checked, when necessary, by means of a spin-down test and comparing the results with either the manufacturer's specified spin-down times or the results of tests carried out on the new meter at the time of installation under identical conditions. Where necessary, the manufacturer's recommended remedial action shall be followed.

Spin-down tests are carried out in a draught-free

F-3.2 Designer Company, that designs and constructs metering facilities and purchases multipath ultrasonic meters.

F-3.3 Inspector Representative of the Designer, who visits the manufacturer's facilities for quality assurance purposes.

F-3.4 Manufacturer Company, that designs, manufactures, sells and delivers multipath ultrasonic meters. Company that operates multipath ultrasonic meters and performs normal maintenance.

F-3.5 Signal Processing Unit, the portion of the multipath ultrasonic meter that is made up of the electronic microprocessor system.

F-3.6 USM Multi-path Ultrasonic Meter, for measuring gas flow rates.

F-4 OPERATING CONDITIONS

F-4.1 Pressures

Ultrasonic transducers used in USM require a minimum gas density (a function of pressure) to ensure acoustic coupling of the sound pulses to and from the gas. Therefore, the designer shall specify the expected minimum operating pressure as well as the maximum operating pressure.

F-4.2 Temperatures, Gas and Ambient

The USM should operate over a flowing gas temperature range of $(-)$ 25° to 55°C. The designer shall specify the expected operating gas temperature range.

The operating ambient air temperature range shall be at a minimum $(-)$ 25° to 55°C. This ambient temperature range applies to the meter body with and without gas flow, field-mounted electronics, ultrasonic transducers, cabling, etc.

The manufacturer shall state the flowing gas and ambient air temperature specifications for the multipath ultrasonic meter, if they differ from the above.

F-4.3 Gas Flow Considerations

The flow rate limits that can be measured by a USM are determined by the actual velocity of the flowing gas. The designer should determine the expected gas flow rates and verify that these values are within the q_{Min} , q_t and q_{Max} specified by the manufacturer. The accuracy requirement for operation within q_{Min} , q_t and q_{Max} stated. The designer should take into account the maximum velocity for noise and piping safety (erosion, thermo wave vibrations, etc) in design.

USM have the inherent capability of measuring flow in either direction with equal accuracy; that is, they

are bi-directional. The designer should specify if bi-directional measurement is required so that the manufacturer may properly configure the SPU parameters.

F-4.4 Upstream Piping and Flow Profiles

Upstream piping configurations may adversely affect the gas velocity profile entering a USM to such an extent that measurement error occurs. The magnitude of the error, if any, will be a function of the meter's ability to correctly compensate for such conditions. The designer should consult the manufacturer and review the latest meter test results to evaluate how the accuracy of a USM may be affected by a particular piping installation configuration.

F-5 METER REQUIREMENTS

The meter body and all other parts, including the pressure-containing structures and external electronic components, shall be designed and constructed of materials suitable for the service conditions for which the meter is rated, and in accordance with any codes and regulations applicable to each specific meter installation, as specified by the designer.

F-5.1 Meter Body

F-5.1.1 Maximum Operating Pressure

Meters shall be manufactured to meet the requirement of common pipeline flange. The maximum design operating pressure of the meter shall be the lowest of the maximum design operating pressure of the following: meter body, flanges, transducer connections, transducer assemblies.

The required maximum operating pressure shall be determined using the applicable codes for the jurisdiction in which the meter will be operated and for the specified environmental temperature range. The designer should provide the manufacturer with information on all applicable codes for the installation site and any other requirements specific to the operator.

F-5.1.2 Corrosion Resistance

All wetted parts of the meter shall be manufactured of materials compatible with natural gas and related fluids.

All external parts of the meter shall be made of a non-corrosive material or sealed with a corrosion-resistant coating suitable for use in atmospheres typically found in the natural gas industry, and/or as specified by the designer.

F-5.1.3 Meter Body Lengths and Bores

The manufacturers should specify overall face-to-face length of the meter body with flanges, for each flange

class and diameter. The designer, as an option, may specify a different length to match existing piping requirements.

The USM bore and the adjacent upstream pipe along with flanges should have the same inside diameter to within 1 percent of each other. For bi-directional applications, both ends of the meter shall be considered upstream.

F-5.1.4 Ultrasonic Transducer Ports

As natural gas may contain some impurities (for example, light oils or condensates), transducer ports shall be designed in a way that reduces the possibility of liquids or solids accumulating in the transducer ports.

If specified by the designer and available from the manufacturer, the meter shall be equipped with valves and necessary additional devices, mounted on the transducer ports in order to make it possible to replace the ultrasonic transducers without de-pressurizing the meter run. In that case, a bleed valve may be required in addition to the isolation valve to ensure that no pressure exists behind a transducer before releasing the extraction mechanism.

F-5.1.5 Pressure Tap

At least one pressure tap shall be provided for measuring the static pressure in the meter. Each pressure tap hole shall be between 3 mm and 10 mm nominal in diameter and cylindrical over a length at least 2.5 times the diameter of the tapping measured from the inner wall of the meter body.

The tap hole edges at the internal wall of the meter body shall be free of burrs and wire edges, and have minimum rounding.

For a meter body with a wall thickness less than 8 mm, the hole shall be 3 mm nominal in diameter.

Female pipe threads shall be provided at each pressure tap for a 6 mm NPT or 12 mm NPT isolation valve. Turning radius clearance shall be provided to allow a valve body to be screwed directly into the pressure tap. Pressure taps can be located at the top, left side, and/or right side of the meter body. Additional taps may provide the designer with flexibility in locating pressure transducers for maintenance access and proper drainage of gauge line condensates back into the meter body.

F-5.1.6 Miscellaneous

The meter shall be designed in such a way that the bodies will not roll when resting on a smooth surface with a slope of up to 10 percent. This is to prevent damage to the protruding transducers and SPU when

the USM is temporarily set on the ground during installation or maintenance work.

The meter shall be designed to permit easy and safe handling of the meter during transportation and installation. Hoisting eyes or clearance for lifting straps shall be provided.

F-5.1.7 Meter Body Markings

A nameplate containing the following information shall be affixed to the meter body:

- a) manufacturer, model number, serial number and month and year manufactured;
- b) meter size, flange class and total weight;
- c) internal diameter;
- d) maximum and minimum storage temperatures;
- e) body design code and material, and flange design code and material;
- f) maximum operating pressure and temperature range;
- g) maximum and minimum actual (at flowing conditions) volumetric flow rate /h;
- h) direction of positive or forward flow; and
- j) purchase order number, shop order number and/or user tag number (optional).

Each transducer port shall be permanently marked with a unique designation for easy reference. If markings are stamped on the meter body, low stress stamps that produce a rounded bottom impression shall be used.

F-5.2 Ultrasonic Transducers

F-5.2.1 Specifications

The manufacturers should state the general specifications of their ultrasonic transducers, such as critical dimensions, maximum allowable operating pressure, operating pressure range, operating temperature range and gas composition limitations.

The manufacturer should specify the minimum operating pressure based on the ultrasonic transducer model, USM size and expected operating conditions. This minimum pressure shall be marked or tagged on the USM to alert the operator's field personnel that the meter may not register flow at reduced pipeline pressures.

F-5.2.2 Rate of Pressure Change

Sudden depressurization of an ultrasonic transducer can cause damage if a trapped volume of gas expands inside the transducer. If necessary, clear instructions shall be provided by the manufacturer for depressurization and pressurization of the meter and

transducers during installation, start-up, maintenance and operation.

F-5.2.3 Exchange

It shall be possible to replace or relocate transducers without a significant change in meter performance. This means that after an exchange of transducers and a possible change of SPU software constants directed by the manufacturer, the resulting shift in the meter's performance shall not be outside the limits of the performance requirement. The manufacturer should specify procedures to be used when transducers have to be exchanged, and possible mechanical, electrical or other measurements and adjustments have to be made.

F-5.2.4 Transducer Tests

Each transducer or pair of transducers shall be tested by the manufacturer and the results documented as part of the USM quality assurance programme. Each transducer shall be marked or tagged with a permanent serial number and be provided with the general transducer. If the SPU requires specific transducer characterization parameters, each transducer or transducer pair should also be provided with test documentation that contains the specific calibration test data, calibration method used and characterization parameter(s).

F-5.3 Electronics

F-5.3.1 General Requirements

The USM electronics system, including power supplies, microcomputer, signal processing components and ultrasonic transducer excitation circuits, may be housed in one or more enclosures mounted either in field or remote and are referred to as a Signal Processing Unit (SPU).

Optionally, a remote unit containing the power supplies and the operator interface could be installed in a non-hazardous area and connected to the SPU by multi-conductor cable.

The SPU should operate over its entire specified environmental conditions within the meter performance requirements. It should also be possible to replace the entire SPU or change any field replacement module without a significant change in meter performance.

The system should contain a watch-dog-timer function to ensure automatic restart of the SPU in the event of a programme fault or lock-up.

The meter should operate from a power supply of nominal 120 V ac or 240 V ac at 50 or 60 Hz or from nominal 12 V dc or 24 V dc power supply/battery systems, as specified by the designer.

F-5.3.2 Output Signal Specifications

The SPU shall be equipped with at least one of the following outputs:

- a) serial data interface; and
- b) frequency, representing flow rate at line conditions.

The meter may also be equipped with an analog (4-20 mA, dc) output for flow rate at line conditions. Flow rate signal shall be scaleable up to 120 percent of the meter's maximum flow rate, q_{Max} .

A low-flow cutoff function shall be provided that sets the flow rate output to zero when the indicate flow rate is below a minimum value (not applicable to serial data output).

Two separate flow rate outputs and a directional state output or serial data values shall be provided for bi-directional applications to facilitate the separate accumulation of volumes by the associated flow computer(s) and directional state output signal.

All outputs shall be isolated from ground and have the necessary voltage protection to meet the electronics design testing requirements.

F-5.3.3 Electrical Safety Design Requirements

The design of the USM, including the SPU, shall be analyzed, tested and certified by an applicable laboratory, and then each meter shall be labelled as approved for operation. Intrinsically safe designs and explosion proof enclosure designs are generally certified and labelled. The designer must specify requirement to achieve a more conservative installation design.

Cable jackets, rubber, plastic and other exposed parts shall be resistant to ultraviolet light, flames and grease.

F-5.4 Computer Programmes

F-5.4.1 Configuration and Maintenance Software

The meter shall be supplied with a capability for local or remote configuring of the SPU and for monitoring the operation of the meter. As a minimum, the software shall be able to display and record the following measurements: flow rate at line conditions, mean velocity, average speed of sound, speed of sound along each acoustic path and ultrasonic acoustic signal quality received by each transducer. As an option, the manufacturer can provide these software functions as part of the meter's embedded software.

F-5.4.2 Inspection and Auditing Functions

It shall be possible for the auditor or the inspector to

view and print the flow-measurement configuration parameters used by the SPU; for example, calibration constants, meter dimensions, time averaging period and sampling rate.

Provisions shall be made to prevent an accidental or undetectable alteration of those parameters that affects the performance of the meter. Suitable provisions include a sealable switch or jumper, a permanent programmable read-only memory chip or a password in the SPU.

F-5.4.3 It shall be possible for the auditor to verify that all algorithms, constants and configuration parameters being used, in any specific meter, are producing the same or better performance as when the meter design was originally flow-tested or when the specific meter was last flow-calibrated and any calibration factors were changed. The auditor may have to rely on the manufacturer for portions of this verification because of the proprietary nature of some USM algorithms.

NOTE — Clause 5.4.3 is an optional clause.

F-5.4.4 Alarms

The following alarm-status outputs should be provided in the form of fail-safe, dry, relay contacts or voltage-free solid-state switches isolated from ground:

- a) *Output invalid*: when the indicated flow rate at line conditions is invalid;
- b) *Trouble*: when any of several monitored parameters fall outside of normal operation for a significant period of time (optional); and
- c) *Partial failure*: when one or more of the multiple ultrasonic path results is not usable (optional).

F-5.5 Noise Issue in Ultrasonic Meter

The speed of sound measured by a USM, the 'measured SOS' (MSOS), is influenced by:

- a) gas composition,
- b) pressure,
- c) temperature,
- d) changes in the geometry of the measurement section, and
- e) changes in transit time measurement (by the meter).

The speed of sound may be calculated from measured values of pressure, temperature and gas composition using AGA 10 the 'theoretical SOS' (TSOS).

F-5.6 Absolute SOS Comparison

If both MSOS and TSOS are available they may be compared: absolute comparison.

Differences between MSOS and TSOS may indicate;

- a) Asynchronous determination of MSOS and TSOS due to fluctuations in gas composition and analysis time lag.
- b) Malfunction of:
 - 1) USM,
 - 2) Pressure measurement,
 - 3) Temperature measurement, and
 - 4) Gas composition measurement.
- c) Depositions on the transducer(s) and/or meter body which changes the path length.

Statistical techniques may be helpful for monitoring MSOS and TSOS over time.

F-6 PERFORMANCE REQUIREMENTS

This section specifies a set of minimum measurement performance requirements that USM must meet. If a meter is not flow-calibrated, the manufacturer shall provide sufficient test data confirming that each meter shall meet these performance requirements. The designer may also specify that a meter be flow-calibrated. If a meter is flow-calibrated, then it shall meet the same minimum measurement performance requirements before the application of any calibration-factor adjustment.

The amount of calibration-factor adjustment, therefore, shall be within the error limits stated in the performance requirements. This is to ensure that a major flaw in the meter is not masked by a large calibration-factor adjustment. Calibration-factor adjustments are made to minimize a meter's measurement bias error. The designer is referred to Annex A and for an explanation of the methods and benefits of flow-calibrating a meter and for calibration-factor adjustment. The design should also follow carefully. Any installation effect will add to the overall measurement uncertainty.

For each meter design and size, the manufacturer shall specify flow-rate limits for q_{Min} , q_t and q_{Max} as defined in. Each USM, whether flow-calibrated or not, shall perform within the more accurate measurement range for gas flow rates from q_t to q_{Max} and within the less accurate range for gas flow rate less than q_t but greater than or equal to q_{Max} as defined.

F-6.1 General

The general flow-measurement performance of all USM shall meet the following requirements, prior to making any calibration-factor adjustment.

F-6.1.1 Large Meter Accuracy

USM 300 mm (nominal) diameter size and larger shall meet the following flow-measurement accuracy

requirements, prior to making any calibration-factor adjustment.

Maximum Error:

± 0.7 percent for $q_i \leq q_t \leq q_{Max}$
 ± 1.4 percent for $q_{Min} \leq q_i < q_t$ (see Fig. 11)

F-6.1.2 Small Meter Accuracy

USM less than 300 mm (nominal) diameter shall meet the following flow-measurement accuracy requirements, prior to making any calibration-factor adjustment. Note that the requirements for the smaller meters have been relaxed slightly because of the difficulty in measuring acoustic transit times in turbulent gas flow when the path lengths are shorter.

F-7 INDIVIDUAL METER TESTING REQUIREMENTS

Prior to the shipment of each USM to the designer or the operator, the manufacturer shall perform the following tests and checks on each meter. The results of all tests and checks performed on each meter shall be documented by the manufacturer and submitted to the designer or the operator.

F-7.1 Leakage Tests

Every USM, complete with transducers and transducer isolation valves (if used), shall be leak-tested by the

manufacturer after final assembly and prior to shipment to the designer or flow-calibration facility. The test medium shall be an inert gas, such as nitrogen. The leak test pressure shall be 1.25 times maximum working pressures maintained for a minimum of 15 min, with no leaks detectable with a non-corrosive liquid solution or an ultrasonic leak detector. This leak test does not preclude the requirements to perform a hydrostatic qualification test.

F-7.2 Dimensional Measurements

The manufacturer shall measure and document the average internal diameter of the meter, the length of each acoustic path between transducer faces and the axial (meter body axis) distance between transducer pairs.

The average internal diameter shall be calculated from a total of 12 inside diameter measurements or the equivalent determined by a coordinate measuring machine. Four internal diameter measurements (one in the vertical plane, another in the horizontal plane and two in planes approximately 45° from the vertical plane) shall be made at 3 m cross-sections:

- a) near the set of upstream ultrasonic transducers,
- b) near the set of downstream transducers, and
- c) halfway between the two transducer sets.

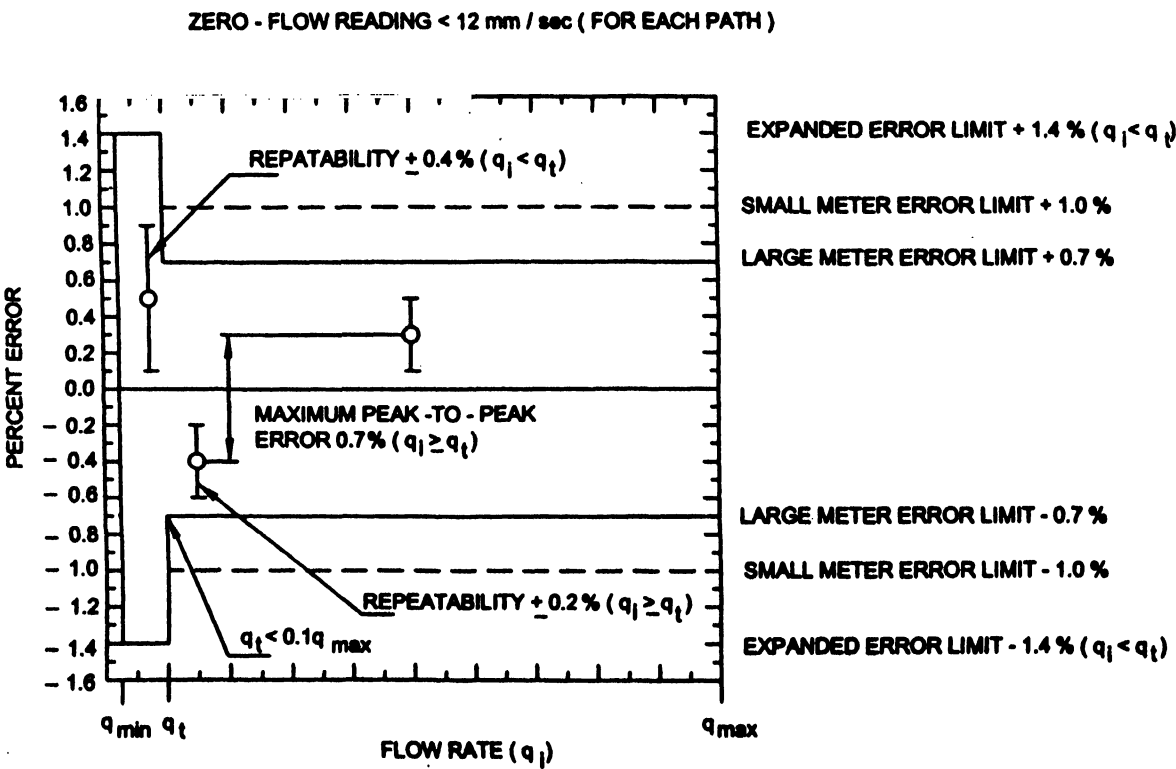


FIG. 11 PERFORMANCE SPECIFICATION SUMMARY

If the acoustic path lengths or the axial distances between ultrasonic transducer pairs cannot be directly measured, then the unknown distances shall be calculated using right-angle trigonometry and distances that can be measured directly. Where the measurement of angles is difficult and the result is imprecise, such measurements shall not be used to calculate the required distances.

The meter body temperature shall be measured at the time these dimensional measurements are made. The measured lengths shall be corrected to an equivalent length at a meter body temperature at ambient condition by applying the applicable coefficient of thermal expansion for the meter body material. The individual corrected lengths shall then be averaged and reported to the nearest 0.01 mm.

All instruments used to perform these measurements shall have valid calibrations traceable to national/international standards.

These measurements and calculations shall be documented on a certificate, along with the name of the meter manufacturer, meter model, meter serial number, meter body temperature at the time dimensional measurements were made, date, name of the individual who made the measurements and name of the inspector if present.

F-7.3 Zero-Flow Verification Test (Zero Test)

To verify the transit-time measurement system of each meter, the manufacturer shall perform a Zero-Flow Verification Test. The manufacturer shall document and follow a detailed test procedure that includes the following elements, at a minimum.

After blind flanges are attached to the ends of the meter body, the meter shall be purged of all air and pressurized with a pure test gas or gas mixture. The selection of the test gas shall be the responsibility of the manufacturer. However, the acoustic properties of the test gas must be well known and documented.

The gas pressure and temperature shall be allowed to stabilize at the outset of the test. The gas velocities for each acoustic path shall be recorded for at least 30 s. The mean gas velocity and standard deviation for each acoustic path shall then be calculated.

Adjustments to the meter shall be made as necessary to bring the meter performance into compliance with the manufacturer's specifications and the specifications stated in this report.

If the measured speed-of-sound values are compared with theoretical values, the theoretically determined value shall be computed using a complete compositional analysis of the test gas, precise

measurements of the test gas pressure and temperature and the equation of state used in 'Detail Characterization Method'.

As part of the test procedure, the manufacturer shall document the ultrasonic transducer serial numbers and their relative locations in the meter body. The manufacturer shall also document all parameters used by the meter; for example, transducer/electronic transit-time delays, incremental timing corrections, and acoustic path lengths, angles, diameters and other parameters used in the calculation of the gas velocity for each acoustic path. The manufacturer should note if the constants are dependent on specific transducer pairs.

The manufacturer may also implement a zero-flow offset factor, in engineering units of positive or negative m/s. This zero-flow offset factor would be applied to the meter's flow rate output. Use of this factor is intended to improve the accuracy of the low gas velocity measurements, while not significantly affecting the accuracy of the higher velocity measurements. This zero-flow offset factor, if used, shall be documented by the manufacturer.

F-7.4 Flow-Calibration

If specified by the designer, the USM shall be flow-calibrated. If a flow-calibration is performed, the following nominal test flow rates are recommended, at a minimum: q_{Min} , $0.10 q_{Max}$, $0.25 q_{Max}$, $0.40 q_{Max}$, $0.70 q_{Max}$, and q_{Max} . The designer may also specify additional flow-calibration tests at other flow rates.

Flow-calibration tests shall be performed at a gas pressure, temperature and density near the expected average operating conditions as specified by the designer. Tests at any other specific pressure temperature and gas density range may be performed, if necessary. The designer may also require that specific piping configurations and/or flow conditioners be used during flow-calibration, understanding that differences in upstream piping configurations may influence meter performance.

It is recognized that it may not be possible to test large USM up to their maximum capacity because of the limitations of currently available test facilities. In such cases, the designer may specify a lower flow rate instead of q_{Max} . The manufacturer should state on an applicable documents if a reduced q_{Max} was used during flow-calibration tests.

The upstream flange and piping internal diameters should match and be aligned with the meter under test.

The test measurements performed by a flow-calibration facility shall be traceable with current calibration certificates to the applicable national/international standards. Any property or thermo physical values (for

example, density, compressibility, speed of sound, critical flow factor, etc) used during flow-calibration shall be computed from 'Detailed Characterization Method Equation of State (see Annex G)'.

F-7.4.1 Calibration Factors Adjustment

If a meter is flow-calibrated, the calibration factors should normally be applied to eliminate any indicated meter bias error. Some suggested methods of applying calibration factors are:

Using flow-weighted mean error (FWME) over the meter's expected flow range.

Using a more sophisticated error correction schedule (for example, a multi-point or polynomial algorithm, a piece-wise linear interpolation method, etc) over the meter's range of flow rates.

For bi-directional flow-calibrations, a second set of calibration factors may be used for reverse flow. If an offset factor was established during the zero-flow validation tests, it may be revised based on the results of the flow-calibration to optimize the meter's overall accuracy performance. The manufacturer shall document such a change in this factor and alert the operator that the zero-flow output may have some intentional bias in order to improve accuracy at q_{Min} .

F-7.4.2 Test Reports

The results of each test shall be documented in a written report supplied to the designer or the operator by the manufacturer. For each meter, the report shall include, at a minimum:

- a) name and address of the manufacturer,
- b) name and address of the test facility,
- c) model and serial number,
- d) SPU firmware revision number,
- e) date(s) of the test,
- f) name and title of the person(s) who conducted the tests,
- g) a written description of the test procedures,
- h) the upstream and downstream piping configurations,
- j) a diagnostic report of the software configuration parameters,

- k) all test data, including flow rates, pressures, temperatures, gas composition and the measurement uncertainty of the test facility, and
- m) a description of any variations or deviations from the required test conditions.

At least one copy of the complete report shall be sent to the designer or the operator and one copy retained in the manufacturer's files. The manufacturer shall ensure that the complete report is available to the operator on request, for a period of 10 years after shipment of any meter.

F-7.5 Quality Assurance

The manufacturer shall establish and follow a written comprehensive quality-assurance programme for the assembly and testing of the meter and its electronic system (for example ISO 9000). This quality assurance programme shall be available to the inspector.

F-8 INSTALLATION REQUIREMENTS (see Annex M)

This section is directed to the designer to ensure that the USM will be installed in a suitable environment and in a piping configuration that allows the USM to meet the expected performance requirements.

F-9 MAINTENANCE (see Annex N)

The operator should follow the manufacturer's recommendations for maintenance. Periodic maintenance could be as simple as monitoring several SPU diagnostic measurements, such as signal quality and speed of sound for each acoustic path. For example, it may be possible to detect an accumulation of deposits on the transducer faces by measuring a reduction in the received ultrasonic pulse strength.

When possible, the operator should verify that the USM measures near zero when no gas is flowing through the meter. When performing this test, the operator should bypass or defeat any low flow cut-off function and be aware that any meter-run temperature differences will cause thermal convection currents of gas to circulate inside the meter, which the USM may measure as a very low flow rate.

ANNEX G
(Clause F-7.4)

MULTI-PATH ULTRASONIC METER FLOW-CALIBRATION ISSUES

G-1 FLOW-CALIBRATION BY MULTI-PATH ULTRASONIC METER

The flow-measurement accuracy permits a multipath ultrasonic meter to have a maximum error of up to ± 7 percent and a maximum peak-to-peak error of 7 percent for gas flow rates between q_i and q_{Max} for meters (nominally) 300 mm in diameter or greater. Similarly, for meters (nominally) less than 300 mm in diameter, the maximum error can be as much as ± 1.0 percent and the maximum peak-to-peak error can be 0.7 percent. As the following example illustrates, multi-path ultrasonic meters may operate within these allowable measurement accuracy envelopes, but still produce significant and costly errors in terms of the measured gas volume. One effective means, of minimizing the measurement uncertainty of a multi-path ultrasonic meter is to flow-calibrate the meter.

Example:

A multi-path ultrasonic meter manufacturer rates the flow capacity of 200 mm diameter USM as follows:

$$\begin{aligned} q_{Max} &= 2\,476.25 \text{ m}^3/\text{h} \\ q_i &= 212.25 \text{ m}^3/\text{h} \\ q_{Min} &= 106.125 \text{ m}^3/\text{h} \end{aligned}$$

Flow-calibration of this meter at a test laboratory yields the following results, after averaging multiple test runs near each of the recommended nominal test rates (RNTR).

The flow-calibration data from Table 1 are plotted as open circles on Fig. 12.

To estimate the error in the volume of gas measured

by this meter, assume that, in field service, the gas is typical pipeline-grade quality and that it flows through the USM at a rate of 1 709.75 m³/h (that is, roughly 0.7 q_{Max}) at a line pressure of 4 137 kPa. For this operating condition, the flow-calibration data indicate that the meter will underestimate the flow rate by 0.372 percent (see Table 1). If this flow rate is held constant for a year, the resulting measurement error is nearly 90 million standard cubic feet of gas per year. Also, note that the error, in terms of the measured volume of gas, is proportional to the square of the UM diameter, so a comparable percentage error for a 500 mm diameter meter would be more than 500 million standard cubic feet of gas per year.

Also note, from the example above, that the magnitude and direction (that is, overestimation or underestimation) of the measurement error of the USM is a function of the flow rate. That is, in this case, the UM over predicts the flow rate on the low end of the operational range and under predicts on the high end of the range. Furthermore, the meter error can be substantially corrected by using the flow-calibration data. The following discussion explains how test-flow data can be used to correct or minimum meter error.

NOTE — The individual data points in Fig.12 represent averaged values for multiple test runs near each of the recommended nominal test rates.

G-2 METHODS FOR CORRECTING A USM FLOW-MEASUREMENT ERROR

The above example demonstrates the potential value of minimizing a USM measurement inaccuracy or uncertainty. The total flow-measurement error of a

Table 1 Flow-Calibration Data for an 200 mm Diameter USM
(Clause G-1)

SI No.	RNTR	Nominal Test Rate m ³ /h	Actual Test Rate — Reference Meter m ³ /h	Meter Reported Rate m ³ /h	USM Error ¹⁾ Percent
(1)	(2)	(3)	(4)	(5)	(6)
i)	q_{Min}	106.125	98.342 5	99.276 4	+0.953
ii)	0.10 q_{Max}	247.625	194.987	195.722 8	+0.376
iii)	0.25 q_{Max}	619.062 5	622.034	620.053	−0.318
iv)	0.40 q_{Max}	990.5	1 069.768	1 066.401	−0.315
v)	0.70 q_{Max}	1 733.375	1 709.745	1 703.377	−0.372
vi)	q_{Max}	2 476.25	2 447.95	2 438.979	−0.366

¹⁾ The 'Meter Reported Rate' has been rounded to the nearest whole acf/h. The 'USM Error' is based on the values for the 'Meter Reported Rate' prior to rounding and the 'Actual Test Rate- Reference Meter'.

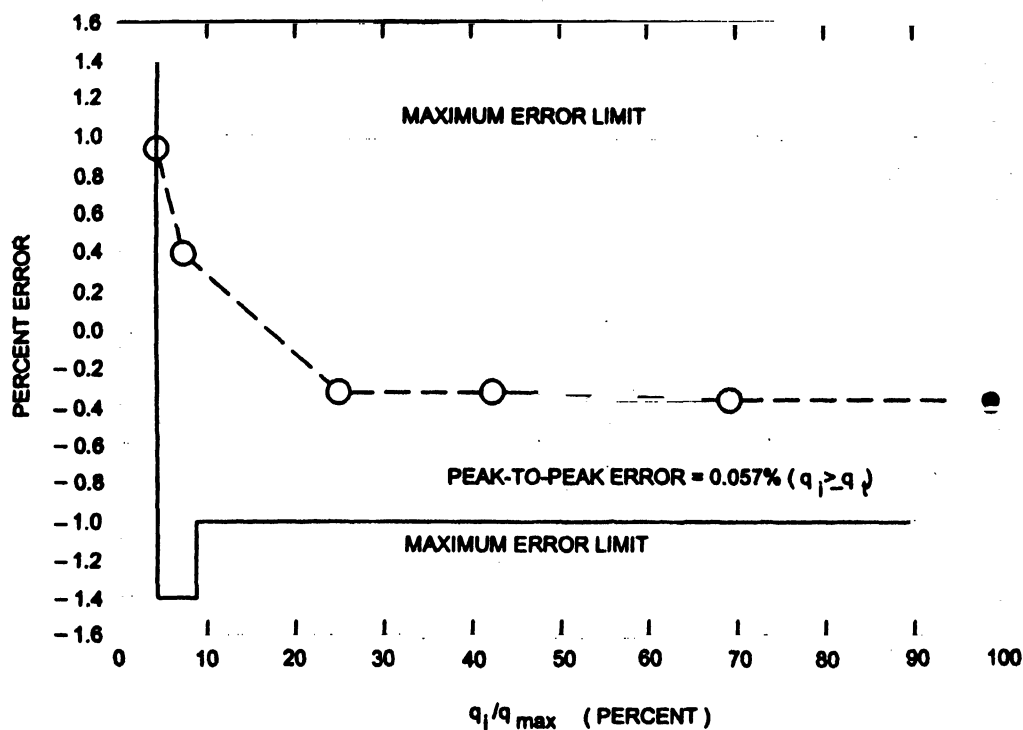


FIG. 12 UNCORRECTED FLOW-CALIBRATION DATA FOR 200 mm DIAMETER USM

USM consists of two parts: (a) random (or precision) errors, and (b) systematic (or bias) errors. Random errors can be caused by various influences on a meter's operation. Random errors normally follow a certain statistical distribution. The magnitude of the random error can usually be reduced by acquiring multiple measurement samples and then applying accepted statistical principles. Systematic errors normally cause repeated USM measurement readings to be in error (for some unknown reason) by roughly the same amount. In most cases, flow calibration of a USM can help eliminate or, at least, minimize the measurement error of the meter. Operational experience has shown that, in most cases, the major portion of the total flow-measurement error of an uncalibrated USM is due to systematic error.

Due to machining tolerances, variations in component manufacturing processes, variations in the meter assembly process and other factors, each USM has its own unique operating characteristics. Thus, to minimize a particular USM flow-measurement uncertainty, the manufacturer can flow-calibrate a USM and then use the calibration data to correct or compensate for the USM measurement error. More than one error correction technique is available to the manufacturer, depending on the meter application and the needs of the operator.

Following is a description of an error correction technique that utilizes a single calibration-factor

correction the flow-weighted mean error (FWME) factor. If a USM flow-measurement output is linear over the operational flow range of the meter, the FWME correction method is effective at minimizing the measurement uncertainty of the meter. Other single calibration-factor correction techniques are also available. If a USM flow-measurement output is non-linear over the meter's operational range, more sophisticated error correction techniques can be applied. For instance, a higher order curve fit algorithm, such as a second- or third-order polynomial equation can be used to characterize the meter's output, based on the available test data. An exhaustive discussion of the various meter error correction techniques is beyond the scope of this discussion. The designer or operator should consult with the manufacturer regarding the available options for a particular USM.

G-3 EXAMPLE OF A FLOW-WEIGHTED MEAN ERROR (FWME) CALCULATION

The calculation of a meter's FWME from actual flow-test data is a method of calibrating a meter when only a single calibration-factor correction is applied to the meter's output. Application of this factor to a USM output is similar to the use of an index gear ratio in a turbine or rotary flow meter. As noted above, use of the FWME factor is only one of several alternative methods of adjustment to a USM calibration to minimize the flow-measurement uncertainty of the meter.

The example used in G-1 will now be used to demonstrate how to calculate the FWME for 200 mm diameter USM that has been flow-calibrated under operating conditions similar to those that the meter

For this example, the FWME is $-0.309\ 3$ percent and the single calibration factor, F , is calculated to be $1.003\ 1$. By multiplying the USM output by $1.003\ 1$ (that is, by applying the calibration factor), the

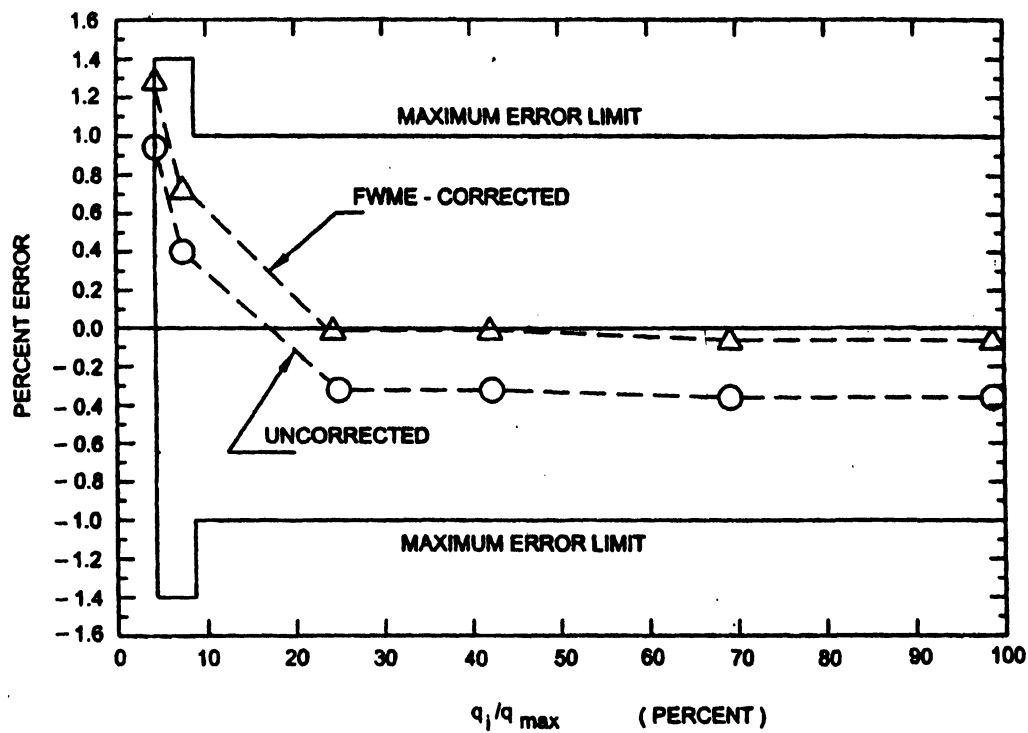


FIG. 13 UNCORRECTED AND FWME-CORRECTED FLOW-CALIBRATION DATA FOR 200 mm DIAMETER USM

performance requirements while operating under the influences and disturbances specified in the current revisions of OIML R 6, 'General Provisions of Gas Volume Meters', and OIML D 11, 'General Requirements for Electronic Measuring Instruments'. OIML is the Organization Internationale de Metrologie L gale, that is the International Organization of Legal Metrology. OIML publishes these documents for the expressed purpose of harmonizing national performance requirements and testing procedures for gas meters.

For the climatic conditions the requirements shall be for class 4K3, open locations with average climatic conditions, thus excluding polar and desert environments. For the mechanical conditions the requirements shall be for class 3/4M5, locations with significant or high levels of vibration and shock for example, transmitted from adjacent compressors. The combination of these two conditions leads to OIML class F for determining the severity level for each test.

Type test includes flow tests for the determination of the L_{Min} of the calibration facility in order to find the upstream piping configuration defining a reference

flow condition. This will be the preferred set up for conducting the flow-calibrations.

G-4.2 Accuracy

The accuracy limits of 6.1.1 shall be met within q_{Max} design and q_{Min} .

The tests shall be conducted under undisturbed flow conditions with the following flow rates: 120 percent, 100 percent, 70 percent, 40 percent, 25 percent, 10 percent, 5 percent of q_{Max} design.

The duration of one measurement shall be at least 300 s, 3 times 100 s or 400 D/V (where D is the inner diameter of meter and V is the mean flow velocity), whichever is larger.

The repeatability test shall be conducted for at least one flow rate below q_t and at least one flow rate above q_t . For each of these flow rates 10 single measurements shall be taken with the duration of the measurement as given above.

For the reproducibility test the same meter shall be tested under exactly the same installation conditions with a time difference of at least 1 month.

ANNEX H

(Clause 6.2.1)

ESTIMATION OF UNCERTAINTY

H-1 INTRODUCTION

The purpose of uncertainty analysis is two-fold. At the design stage, it identifies weaknesses in the design of the metering installation and indicates the action necessary to eliminate them. It also permits the estimation of the level of uncertainty likely to be achieved in practice.

For existing installations, it serves a similar purpose in identifying possible modifications should the predicated level of uncertainty be too high.

An uncertainty analysis should, always, be carried out during the design of a new installation.

H-2 GENERAL PRINCIPLES

Whenever a measurement of flow rate is made, the value obtained is simply the best estimate of the true flow rate which can be obtained from the experimental data. In practice, the true flow rate may be slightly greater or less than this value. The following describe the calculations required in order to arrive at a statistical estimate of the interval within which the true flow rate may be expected to lie.

H-3 UNCERTAINTY

Owing to the very nature of physical measurements, it is impossible to effect the measurement of a physical quantity without error. The usefulness of the measurements greatly enhanced if a statement of the possible error accompanies the result but it is rarely possible to give an absolute upper limit to the value of the error. It is, therefore, more practicable to give an interval or range within which the true value of the measured quantity can be expected to lie with a suitably high probability. This interval is termed the uncertainty of measurement and the confidence level associated with the uncertainty indicates the probability that the interval quoted will conclude the true value of the quantity being measured.

There is a fundamental difference between error and the uncertainty of a measurement, which is that the former is, by definition, unknown whereas the latter may be estimated.

H-4 RELATIONSHIP BETWEEN UNCERTAINTY AND CONFIDENCE LEVEL

The uncertainty and the confidence with which it can be used are closely related; the wider the uncertainty, the greater is the confidence that the true measurement

will be encompassed by this range. This applies even where the confidence level cannot be calculated, for example where the error is systematic in nature. Where the shape of a probability distribution is known it is often possible to calculate a new value for the uncertainty of measurement for a different probability from a given uncertainty and associated probability. It is, however, necessary to reach a compromise between choosing, at the one extreme, a very narrow uncertainty range with a low confidence level and, at the other, a wide uncertainty range with a high confidence level. Nevertheless, the confidence level is an essential part of the uncertainty statement.

Given the adequacy of the data available, the choice of the confidence level at which to work is therefore determined by the implications for those who will use the measurement result. For flow measurement, the adoption of 95 percent as the confidence level to be associated with the uncertainty statement is a suitable compromise between the considerations given above, and will be the policy for these procedures whenever confidence levels can be stated.

H-5 RANDOM AND SYSTEMATIC ERRORS

Random errors are inherent in any installation and are those errors that fluctuate from moment to moment and can be reduced to insignificant levels by taking a large number of measurements.

They may be significant when single or a few flow rate measurements are made but will have a minor effect when estimating the total flow rate of gas passed over substantial periods of time. Where spot measurements of flow are used for control purposes, random effects may be significant. These are best taken into account by performing duplicate calculation to those shown in the following examples, in which the systematic uncertainties shall be replaced by estimated random uncertainties for each parameter. However, the Metering Standards for Gaseous Petroleum Measurements do not require this distinction to be made between random and systematic components.

A major source of errors arises from the performance of instruments in the field and deviation from their initial calibration. These are random in nature and can be minimized by regular recalibration.

Systematic errors derive from the manufacture or calibration of equipment and their magnitude cannot

be reduce by repeated measurement. When flow rate measurement of the highest accuracy is required, systematic uncertainties can be sometimes reduced by having instrumentation calibrated by a number of laboratories which derive their traceabilities from separate independent primary standards.

In the following examples, it will be noted that, although a large number of parameters contribute to the overall uncertainty, most uncertainty calculation are dominated by no more than five parameters. Neglect of the other parameters does not, significantly, change the overall results.

All the examples are presented with uncertainty expressed as percentages for clarity.

H-6 INDEPENDENCE OF VARIABLES

The simplest estimation of uncertainty occurs when the contributing effects are all independent of each other. For example, consider a turbine meter with a density transducer installed. The mass flow rate will be given by:

$$q_m = \frac{f \cdot d}{K}$$

where

- q_m = mass flow rate,
- f = turbine meter frequency output,
- K = meter factor, and
- d = density transducer output.

Uncertainties can be combined on a root sum of squares basis. Hence the uncertainty of the mass flow rate is given by:

$$E_{qm} = (E_k^2 + E_f^2 + E_p^2)^{0.5}$$

where

- E_{qm} = denotes the uncertainty on the mass flow q_m ,
- E_f = denotes the uncertainty on the turbine meter frequency,
- E_k = denotes the uncertainty on the meter factor, and
- E_p = denotes the uncertainty on the density factor.

In this equation, the frequency of the turbine meter, its meter factor and the density transducer output are all treated independently of each other. However, in some installations, the parameters will not be independent and due allowance for this must be made. This is most simply achieved by the use of sensitivity factors as described below.

H-7 SENSITIVITY FACTORS

Consider the case of density determination by the measurement of pressure, temperature and gas

composition. An error in pressure measurement creates an error in density, since.

$$d = \frac{PM}{RTZ}$$

where

- R = universal gas constant,
- T = absolute temperature,
- P = pressure,
- M = molecular weight, and
- Z = compressibility factor.

It also creates an error in Z , which then creates a further error in the calculated density.

The interdependence of P , T , M and Z is treated by calculating sensitivity factors. The sensitivity factor is defined as the percentage change in the calculated flow caused by 1 percent error in anyone variable. It can be calculated from the equation:

$$S_x = \frac{q_m x}{q_m y}$$

where

S = sensitivity factor, and x denotes the parameter concerned and y is another variable.

In the case considered 1 percent error in pressure results in a 1.21 percent error in density, and 1 percent error in temperature results in a 1.84 percent error in density. An error of 1 percent in molecular weight can be shown to generate an error of 1.32 percent in density for this particular example.

Hence the sensitivity factors for this case are:

$$\begin{aligned} S_p &= 1.21 \\ S_t &= 1.84 \\ S_m &= 1.32 \end{aligned}$$

It shall be noted that the International Metering Standards for Gaseous Petroleum Measurements assume that there is no interdependence between P , T , M , and Z and hence the sensitivity factors in those standards are taken as unity.

The effect of sensitivity factors is illustrated in Case 1 and Case 2. The following indicate how systematic uncertainty can be estimated for various types of meters and installations.

H-7.1 Case 1: Turbine Meters

Parameter	Individual Uncertainty	Sensitivity	Variance
Meter factor	0.5	1	0.25
Z	0.25	1	0.06

Total error: 0.72 percent.

Overall uncertainty in Flow measurement = SQRT (Total variance).

The use of more than one meter can reduce the overall uncertainty as the sensitivity of meter factor is modified

if the meters are calibrated at different laboratories. If they are calibrated at the same laboratory, as commonly happens, then the overall uncertainty will not be reduced.

H-7.2 Case 2: Orifice Meters

Sl No.	Parameter	Individual Uncertainty	Sensitivity	Variance
i)	Discharge Coefficient	0.65	1	0.42
ii)	Orifice Bore	0.1	2.3	0.05
iii)	Pressure	0.2	1.21	0.06
iv)	Temperature	0.2	1.84	0.14
v)	Flow Computer	0.1	1	0.01
vi)	Density	0.3	0.5	0.02
vii)	Differential Pressure	0.25	0.5	0.02
viii)	Expansibility	0.05	1	0
ix)	Meter Tube Bore	0.1	0.3	0
Total Variance				0.68

Total error: 0.82 percent.

Overall uncertainty in flow measurement = SQRT (Total variance).

ANNEX J

(Clause 1.1)

SECONDARY INSTRUMENTATION

J-1 REQUIREMENT FOR SECONDARY INSTRUMENTATION

Dependant on the type of meter selected, the requirement for continuous measurements and the output required, for example, mass actual volume, volume at base conditions or energy and the system uncertainty the appropriate secondary instrumentation shall be installed.

For custody transfer purposes, secondary instrumentation shall have calibrations traceable to appropriate International Standards.

J-2 STANDARD UNITS

J-2.1 The gas may be metered in volume or mass units; volumes shall be measured in cubic metres.

Where volume units are used, they shall be converted to standard reference conditions which shall be specified. The reference conditions are 15°C temperature and 1.033 kg/cm² absolute pressure.

J-2.2 Standard Volume Flowrate, q_v

The instantaneous standard volume flow rate of gas

q_{vs} shall be calculated using the following expression:

$$q_{vs} = q_m / \rho_r$$

where

q_m = mass flowrate, and
 ρ_r = density (kgm⁻³) at standard reference conditions.

J-2.3 Energy Flow rate, q_e

The instantaneous standard energy flow rate, q_e shall be calculated using the following expression:

$$q_e = q_{vs} CV$$

where

CV = calorific value of the gas (Mjm⁻³) at the same standard reference conditions as used for q_{vs} .

J-2.4 Details of Secondary Instrumentation

The live measurement is required for pressure and temperature to derive flow. Live measurement of pressure, temperature and gas composition shall be used to derive density and real relative density.

Improvements in accuracy may be made by using a measured temperature to correct the diameters of the meter tube and orifice plate.

J-2.4.1 Differential Pressure Transmitters

Differential pressure transmitters have a significant effect on the overall accuracy of an orifice meter and should, therefore, be selected and installed to meet the required system uncertainty limits.

For custody transfer use, this range shall be limited to 3 : 1.

This is approximately equivalent to 2:1 of flow due to the square root effect of orifice meters.

Where the range of an orifice meter needs to be increased, two or more differential pressure transmitters shall be installed in parallel, each operating over a part of the range. The ranges should overlap and the switch-over points be selected to minimize the uncertainty of the system.

A single 'Auto-rearranging' (Smart) differential pressure transmitter may be used provided that it does not take longer than 5 s to change between ranges. The flow computer should use the value prior to rearranging during the rearranging process.

Differential pressure transmitters shall be of good proven design and sturdy construction. They should have good linearity and repeatability with negligible mounting position effects. High quality transmitters shall be selected with the best accuracy and minimum temperature and pressure effects.

An overall uncertainty of 0.2 percent of span, or better, shall be achieved.

These accuracy levels can only be achieved by proper installation and calibration.

The transmitters shall be mounted adjacent to the meter tube in a weather proof enclosure and consideration shall be given to its temperature control for optimum accuracy.

The impulse lines from the transmitter to the meter tube shall be as short as possible and installed to be self draining such that any condensation formed drains back into the meter tube.

J-2.4.2 Density

Density shall be calculated using pressure, temperature and gas composition using an equation of state. Gas density and compressibility are related by the following formula:

where

- ρ_1 = calculated upstream density, in kgm^3 ;
- P_1 = measured upstream pressure, in kPa;
- T_1 = upstream temperature, in K;
- M_{gas} = molecular weight of the gas;
- R = universal gas constant ($\approx 8\,314.34$ J/K); and
- Z_1 = gas compressibility factor at line conditions.

Alternatively the density shall be calculated from the live measurement of real relative density (RD) using the formula:

$$\rho_1 = \frac{RD \rho_{\text{air}} P_1 T_s Z_s}{P_s T_1 Z_1}$$

where

- ρ_{air} = density of air at base conditions, in kgm^3 ;
- P_s = pressure at base conditions, in kPa;
- T_s = base temperature, in K; and
- Z_s = gas compressibility at base conditions.

$$RD = \frac{(M_{\text{gas}})(Z_{\text{air}})}{(M_{\text{air}})(Z_s)}$$

The method used to calculate density is dependent upon the availability of live measurements, for example, gas composition or RD, and the accuracy required.

J-2.4.3 Pressure Measurement

On orifice meters, the pressure shall be measured at the plane of the upstream pressure tapping ideally, the orifice carrier should have two pairs of tappings: one pair for differential pressure and the other for pressure.

Pressure transmitters shall be of a proven design and sturdy construction. They should have good linearity and repeatability with negligible mounting effects. Transmitters shall be selected to have an uncertainty of 0.15 percent of span or better.

The pressure transmitters shall be mounted and installed in the same manner as the differential pressure transmitters detailed in J-2.4.1.

J-2.4.4 Temperature Measurement

For accurate temperature measurement, a platinum resistance thermometer may be used.

J-2.5 Flow Computers

Each flow computer should,

- a) accept inputs from the flow meter and appropriate combinations of pressure, temperature, relative density and calorific value instruments.
- b) continuously calculate the actual volume flow of gas from the flow meter output and preset calibration data which may be interpolated from the respective flow meter calibration curve, entered into the flow computer.
- c) convert the actual volume to mass and/or standard volume flows and/or energy units.

The meter flows shall be integrated and stored in totalizers. These totalizers shall be non-resettable and be protected against power failure.

J-2.5.2 Selection of flow computers shall be done with RS ports for hook up with the SCADA system for remote monitoring and control.

Each flow computer should have the self monitoring alarm functions and communications capabilities.

The uncertainty of the calculations performed by the flow computers are normally, better than 0.001 percent.

ANNEX K

(Clause 1.1)

GAS PROPERTIES RELATED TO METERING

K-1 GENERAL

In the measurement of gas, a number of physical and chemical properties are necessary for the calculation of the metered quantities. For example, flow measurement used for transfer purposes is, generally, combined with the calorific value of the gas to obtain the energy supplied. For orifice and turbine meters, it may be necessary to know the Reynolds number and hence viscosity and line density, to apply corrections to the meter's calibration constants.

The design of the metering system is, therefore, influenced by the requirements for which the measurement is being made for flow measurement applications, the designer has a choice of routes through the use of secondary instrumentation or through computation of relevant properties from gas composition measurements.

Dependent upon the application the principle gas properties which may be needed for flow measurement include:

- a) viscosity,
- b) isentropic exponent,
- c) calorific value,
- d) gas composition, and
- e) water vapour content.

Whether the determinations are made by on-line instrumentation or by off-line analysis, it is essential that the properties measured or determined are representative of the gas being metered.

K-2 SAMPLING

K-2.1 Sampling shall be carried out at line conditions to provide a representative portion of the gas to an instrument for analysis or for sensing some physical property.

In the case of sampling for on-line measurement, the frequency and volume of the sample will be dictated by the requirements of the on-line instrument. In the case of off-line measurements, the sampling may be manual or automatic.

Where pipelines carry gas of which the composition varies with time, sampling shall be continuous and automatic. However, where the gas is of nominally constant composition, samples may be taken manually. Where the flow rate varies, then consideration shall be given to flow proportional sampling or continuous on-line measurement.

K-2.2 Certain precautions shall be taken during sampling. These should include, as a minimum, that:

- a) the sampling point is located downstream of flow disturbances and where the gas is homogeneously mixed. A sampling point should not be located in a stagnant or dead end pipe section.
- b) sample lines shall be placed above horizontal plane of the pipe and slope so that any liquids separating out can be returned to the pipe or separated from the sample. The line shall be kept as short as possible.

c) materials used be such that there is no chemical interaction with components of the gas or their condensates.

The frequency of sampling shall be programmed to operate on a time or on a flow-weighted basis.

no alteration of the composition. Sampling shall be carried out so that the temperature and pressure of the sample do not drop below the dew-point or the saturation vapour

K-2.6 Sampling Equipment

A sampling unit should consist of an insertion probe, interconnecting line, suitable valving, pressure

ANNEX L

(Clause K-4)

CALCULATION OF CALORIFIC VALUES, DENSITY, RELATIVE DENSITY AND WOBBE INDEX FROM NATURAL GAS COMPOSITION

L-1 CALORIFIC VALUE

L-1.1 Super Calorific Value

The amount of heat which could be released by the complete conversion in air of a specified quantity of gas, in such a way that the pressure p_1 at which the reaction takes place remains constant, and all the products of combustion are returned to the same specified temperature t_1 as that of the reactants, all of these products being in the gaseous state except for water formed by combustion, which is condensed to the liquid state at t_1 .

Where the quantity of gas is specified on a molar basis, the calorific value is designated as $H_s(t_1, p_1)$.

Where the quantity of gas is specified on a volumetric basis, the calorific value is designated as $H_s(t_1, p_1) \cdot V(t_2, p_2)$. Where t_2 and p_2 are the gas volume (metering) reference conditions.

L-1.2 Inferior Calorific Value

The amount of heat which would be released by the complete combustion in air of a specified quantity of gas, in such a way that the pressure p_1 at which the reaction takes place remains constant, and all the products of combustion are returned to the same specified temperature t_1 as that of the reactants, all of these products being in the gaseous state.

On molar, mass and volumetric bases, the inferior calorific value is designated respectively as $H(t_1, p_1)$, $H_1(t_1, p_1)$, and $H_1[(t_1, p_1) \cdot V(t_2, p_2)]$.

L-2 DENSITY

The mass of a gas sample divided by its volume at specified conditions of pressure and temperature.

L-2.1 Relative Density

The density of a gas divided by the density of dry air of standard composition (see Annex B) at the same specified conditions of pressure and temperature. The term ideal relative density applies when both gas and air are considered as fluids which obey the ideal gas law, the term real relative density applies when both gas and air are considered as real fluids.

L-3 WOBBE INDEX

If the flow of the fuel across a burner orifice varies then it follows that the energy produced during combustion will also change. The Wobbe Index is defined as the amount of energy introduced to the burners.

$$\text{Wobbe index} = \frac{\text{Calorific value}}{(\text{Specific gravity})^{1/2}}$$

L-4 COMBUSTION AIR REQUIREMENT INDEX (CARI)

The volumetric flow of a fuel gas through a burner orifice (restriction) is dependent upon the specific gravity of that fuel. Therefore, the amount of air required for complete combustion of a fuel will vary with the density of the fuel gas. The Combustion Air Requirement Index (CARI) is a dimensionless parameter indicating how much air is required for the stoichiometric combustion of a fuel gas.

$$\text{CARI} = \frac{\text{Air/Fuel ratio}}{(\text{Specific gravity})^{1/2}}$$

L-5 ENTHALPY OF TRANSFORMATION

The enthalpy of transformation of a substance from state A to state B is the thermodynamic terminology for the amount of heat release which accompanies the transformation between states. A positive heat release is taken by convention to be a numerically identical negative enthalpy increment. The quantities enthalpy of combustion and enthalpy of vaporization therefore have meanings which shall be contextually self-evident; the term enthalpy correction refers to the (molar) enthalpy of transformation between the ideal and real states of a gas.

L-6 IDEAL GAS AND REAL GAS — AN IDEAL GAS IS ONE WHICH OBEYS THE IDEAL GAS LAW

$$p \cdot V_m = Z(T, p) \cdot R \cdot T$$

where $Z(T, p)$ is a variable, often close to unity, and is known as the compression factor.

ANNEX M

(Clauses 6.5 and F-8)

INSTALLATION AND COMMISSIONING

M-1 INSTALLATION

M-1.1 General Requirements

M-1.1.1 In selecting the location of the meter, consideration shall be given to the requirements for access to operate and maintain it.

M-1.1.2 The meter and secondary instrumentation shall be installed in accordance with certification requirements and should take account of the manufacturer's instructions and the relevant standards and codes of practice.

M-1.1.3 The installation should not be subject to extremes of temperature or vibration and shall be designed and constructed to suit the environment in which it is located, particularly, if offshore. Adequate weather protection shall be installed.

M-1.1.4 The meter shall be installed with the required pipe work configuration, by-passes, flow straightness, filters etc, as detailed in the relevant sections of this standard. Isolation valves shall be fitted at the inlet and outlet of each meter run with a vent valve to facilitate the isolation and venting of the meter run for maintenance. Double block and bleed valves shall be used where maintenance includes opening parts of the system which, normally, contain pressure.

M-1.1.5 Careful consideration shall be given to the choice and operating requirement of secondary instrumentation and the possible need to house equipment in temperature controlled enclosures, or a meter house, to minimize ambient temperature effects upon the accuracy of the equipment.

M-1.1.6 For meters used for custody transfer and taxation purposes applications, secondary instrumentation shall be installed in a meter house. The meter house should have lighting, temperature controlled and have adequate ventilation.

M-1.1.7 On all installations, provision shall be made for the connection and operation of calibration equipment.

M-1.1.8 All meters, secondary instrumentation and equipment associated with the metering system shall be clearly labelled. The label should state the instrument identification number and its function.

M-1.1.9 Material certification for all pressure containing parts shall be retained.

M-1.2 Mechanical Installation

M-1.2.1 The meter associated pipe work should conform to the relevant pipe work installation code and be welded and flanged accordingly.

M-1.2.2 The pipe work shall be supported immediately upstream and downstream of the meter such that no distortion occurs within the meter body.

M-1.2.3 For optimum accuracy, consideration shall be given to thermal insulation of the meter run and secondary instrumentation, particularly if the meter system is likely to be subjected to extreme temperature changes due to solar or wind chill effects.

M-1.2.4 Secondary instrumentation impulse pipe work shall be installed to provide a true reading or, in the case of analyzers, a representative sample. The impulse pipe work should:

- a) be connected to the centre line,
- b) have a full bore isolation valve as close as possible to the connection,
- c) have a slope from the instrument back to the pipeline. If this is not possible then catch pots shall be installed at the low point in the impulse lines,
- d) have a facility at the instrument to allow isolation, venting and calibration, and
- e) be adequately supported and mechanically protected be thermally insulated.

M-1.2.5 Instrumentation should, where possible, be mounted on a stand at a height suitable to allow convenient access for maintenance and calibration.

M-1.3 Commissioning

To ensure that any metering system meets its design performance specification, a series of tests shall be performed before use.

This is particularly important in the case of metering systems used for custody transfer.

M-1.3.1 Manufacturer's Tests

Meters requiring calibration, for example, turbine meters, shall be calibrated over the working ranges of pressure and flow, at an approved facility, to determine the meter characteristics (ideally using the process fluid).

On orifice meters, the meter tube and orifice plate shall be dimensionally checked for compliance with the standard. The measurements recorded are important as

dimensions derived from them will be used in the flow calculation.

Flow computers and database computers shall be tested at the manufacturer's premises to ensure that the required calculations are performed accurately, using the correct equations, and that any reports generated by the system are correct.

All secondary instrumentation shall be tested at the manufacturer's premises and calibration certificates issued.

M-1.3.2 Pre-commissioning

Following installation, the metering system pipe work shall be pressure tested and the electrical equipment checked to ensure safe and reliable operation.

The operation of all equipment, particularly automatic and manual isolation and vent valves shall be checked.

The secondary instrumentation and flow computers shall be calibrated and all constants used in the calculations checked. Where possible, a full system test shall be carried out.

Calibration equipment shall be certified by an accredited calibration laboratory traceable to national/international standards.

M-1.3.3 Commissioning

The metering system pipe work shall be checked to

ensure that no swarf or debris is present and then be tested and purged. The system may be pressurized up to the closed inlet valve.

With the outlet valve closed, the meter shall be slowly pressurized, ideally through by-pass around the inlet valve. When the meter tube is pressurized to full line pressure the inlet valve shall be opened. The outlet valve should then be slowly opened to ensure that the orifice plate or turbine meter is not damaged due to excess live flow.

The maximum flow rating of the meter should never be exceeded.

Orifice plates and turbine meters could be damaged whereas, with ultrasonic meters, the signal might be lost but no permanent damage would occur.

Particular care shall be exercised during commissioning when the downstream pressure is likely to be lower than the upstream pressure and there is a possibility that the maximum flow rating may be exceeded.

On all meters, wherever possible the initial gas flow shall be through a by-pass and not the meter, or the secondary instrumentation shall be isolated. The orifice plate meters used for custody transfer shall be inspected to check for damage to the upstream face and edge.

ANNEX N

(Clause F-9)

OPERATION AND MAINTENANCE

N-1 GENERAL

N-1.1 To ensure that the metering system continues to perform to its design accuracy, routine inspections and calibration shall be based on the required system accuracy, the meter performance and any changes to the process parameters. A record of all calibration results and equipment changes shall be kept.

N-1.2 Regular inspection and maintenance of certified electrical equipment shall be carried out in accordance with the certification requirements and should take account of the manufacturer's instructions and any relevant standards. Documentation and records shall be kept to enable explosion-protected electrical and electronic equipment to be maintained in accordance with its type of protection.

N-1.3 The operation of the meter run and by-pass

valves shall be checked to ensure that they are capable of being fully opened and fully closed and that any status indication is correct. The valves shall be tested to ensure that they do not leak. Any leaks, wire seals, etc, used to indicate closure of by-pass valves shall be checked routinely for integrity (*see Annex R*).

N-1.4 Relevant safety procedures concerning positive isolation of high pressure gas shall be followed when removing meters, orifice plates or other fittings from the line.

N-1.5 The pressure differential across filters shall be checked at predetermined intervals and filters cleaned/changed when necessary.

N-2 TURBINE METERS

N-2.1 Turbine meters shall be removed from the line

and examined for corrosion or other damage. At regular intervals, the turbine meter shall be sent to an approved facility for calibration as detailed in E-6.2.3.

N-2.2 When the operation of a turbine meter is suspected, it shall be removed from the line for inspection and a spin-down test carried out in a draught free environment. Comparisons of measured spin-down times with the manufacturer's as new values will give a good guide to the condition of the meter.

N-2.3 Turbine meters that require periodic lubrication shall be lubricated in accordance with the manufacturer's instruction.

N-3 ORIFICE PLATES

N-3.1 Orifice plates shall be removed for routine inspections or after a disturbance, for example a filter rupture or excessive differential pressure across the plate.

N-3.2 The orifice plates shall be examined visually to ensure that no damage has been sustained, with particular attention to the upstream square edge of the orifice bore and the upstream face. The upstream face of each plate shall be examined with a straight edge to ensure that no warping or distortion has occurred.

N-3.3 The orifice fitting shall be examined to ensure that no debris is present to prevent the proper seating of the orifice in the carrier.

N-3.4 On metering systems used for taxation purposes, the orifice plates shall be measured and certified for conformance with AGA 3 by a recognized authority.

N-4 CALIBRATION OF SECONDARY INSTRUMENTATION

N-4.1 Differential Pressure Transmitters

N-4.1.1 For optimum accuracy in the case of orifice meters, differential pressure transmitters shall be calibrated at the operating pressure.

On applications where optimum accuracy is not a requirement, differential pressure transmitters may be calibrated at ambient pressure and the effects of pressure shift, which can be considerable, included in the uncertainty calculations.

N-4.1.2 In both cases, calibrations shall be carried out using a certified dead-weight tester traceable to national standards.

Calibration can be achieved directly using a dead-weight tester, or indirectly, using a secondary standard of known repeatability that has been verified against a certified device.

N-4.1.3 Ambient calibration shall be carried out with a differential dead-weight tester connected to the high pressure port of the transmitter and with the low pressure port open to ambient pressure.

N-4.1.4 Calibrations shall be carried out with a differential dead-weight tester connected to both high and low ports of the transmitter: The high static pressure is applied to the low port while the high static pressure plus the differential pressure are applied to the high port.

This type of dead-weight tester is susceptible to vibration and is, therefore only suitable for permanent installation in a laboratory or, in some cases, a meter house.

N-4.1.5 When using either ambient or high pressure differential dead-weight testers, consideration shall be given to correcting the weight values for local gravity and temperature to obtain the required accuracy.

N-4.1.6 When use of a high static differential dead-weight tester is not practicable, the footprint method shall be used as an alternative method of high static pressure calibration.

The differential pressure transmitter shall be calibrated at an approved laboratory operating at high static pressure and ambient pressure.

This calibration provides a footprint which indicates the extent of any shift in calibration due to pressure. Provided that the footprint values are repeated in the field at the ambient pressure, allowing for corrections in gravity and temperature, then the transmitter is assumed to be within calibration at high static pressure.

A high static zero check shall be carried out in addition to the footprint check. Transmitters shall be foot printed annually.

N-4.2 Pressure Transmitters

Pressure transmitters shall be isolated from the process pipe work and calibrated with a certified dead-weight tester, either directly or indirectly, by the use of a repeatable secondary standard which has been verified against a certified device.

N-4.3 Temperature Elements

A certified temperature device shall be placed in test thermowell, adjacent to the measuring element, and the reading compared under flowing conditions. If a test thermowell is not available then the measuring element shall be removed from the line and both devices placed in closed proximity in an insulated container in a suitable medium at, approximately, the normal operating temperature.

N-4.4 Gas Chromatographs

The gas chromatographs should automatically perform a calibration daily, using a calibration gas prepared gravimetrically or a standard gas similar to the process gas which is traceable to national standards.

N-4.5 Flow Computers

N-4.5.1 Prior to the start of the tests, the constants entered in the flow computer shall be recorded and checked.

N-4.5.2 Checks shall be carried out on the following:

- Analogue to digital conversion;
- Frequency inputs;

- RTD temperature input;
- Digital to analogue conversion;
- Calculation of density, relative density and calorific value from the gas;
- Composition;
- Calculation of flow rate; and
- Integration of flow rate.

N-4.5.3 When checking the calculation and integration of flow rate, using keypad values, all keypad inputs shall be return to live inputs on completion of tests and all constants recorded and checked.

ANNEX P

(Clause 1.1)

GAS ANALYSIS AND RECORDING CALORIMETERS

P-1 GAS ANALYSIS

P-1.1 Chemical Composition of Natural Gas

Natural gas is a naturally occurring gas mixture, consisting mainly of methane. Table 4 outlines the components and ranges for these values.

There is no guarantee of the following composition at your location nor as a system average. The exact composition at any site will vary among the different

Table 4 Chemical Composition of Natural Gas

Sl No.	Component	Analysis (Mole Percent)	Range (Mole Percent)
(1)	(2)	(3)	(4)
i)	Methane	94.9	87.0-96.0
ii)	Ethane	2.5	1.8-5.1
iii)	Propane	0.2	0.1-1.5
iv)	ISO-Butane	0.03	0.01-0.3
v)	n-Butane	0.03	0.01-0.3
vi)	ISO-Pentane	0.01	trace-0.14
vii)	n-Pentane	0.01	trace-0.04
viii)	Hexane plus	0.01	trace-0.06
ix)	Nitrogen	1.6	1.3-5.6
x)	Carbon dioxide	0.7	0.1-1.0
xi)	Oxygen	0.02	0.01-0.1
xii)	Hydrogen	trace	trace-0.02
xiii)	Specific gravity	0.585	0.57-0.62
xiv)	Gross heating value (MJ/m ³), dry basis ¹⁾	37.8	36.0-40.2

¹⁾ The gross heating value is the total heat obtained by complete combustion at constant pressure of a unit volume of gas in air, including the heat released by condensing the water vapour in the combustion products (gas, air, and combustion products taken at standard temperature and pressure).

regions. The average heating value will depend on the mix of gas supplies and therefore can vary from the value listed in Table 4.

P-1.2 Sulphur

Sulphur content is 5.5 mg/m³ which includes the 4.9 mg/m³ of sulphur in the odourant (mercaptan) added to gas for safety reasons.

P-1.3 Water

The water vapour content of natural gas is less than 80 mg/m³, and is 16 to 32 mg/m³.

P-1.4 Combustion Properties of Natural Gas

Ignition point	593°C
Flammability limits	4 percent to 16 percent (volume percent in air)
Theoretical flame temperature (stoichiometric air/fuel ratio)	1 960°C
Maximum flame velocity	0.3 m/s
Relative density (specific gravity)	0.585
Wobbe index (Btu/scf)	1 328

NOTE — There is no guarantee that the combustion properties at your location will be exactly as shown. The properties shown are an overall average on the Union Gas system.

P-1.5 Chemical Absorption Methods

Chemical absorption techniques are used for analyzing individual components which may be indicative of the

quality of the gas or the efficiency of combustion of the gas. The component may be quantified by the direct change in volume, the intensity of colour of the absorbent, a measurement of the heat generated when absorbed on a reactive surface, etc.

3.1.6 Gas Transport Method

particularly of higher hydrocarbons. Some gas chromatography systems work on the basis of trapping higher hydrocarbon are back flushed through the system and quantified.

It is necessary to carry out regular calibrations, using standard certified mixtures of gases of similar

P-4 RECORDING CALORIMETERS

The recording calorimeter operates on the principle of metering a quantity of gas mixing it with a metered quantity of air burning it in a suitable combustion chamber and cooling the flue gases in a heat exchanger with a metered quantity of air or water. The temperature rise of the gas or water is accurately measured and the calorific value inferred from a calibration using a gas of known calorific value.

In the recording type calorimeters, the meters for measuring the gas, the air for combustion and the exchange air are geared together in a common water bath so that a constant air to gas ratio is obtained. As ambient temperature and pressure variations affect each of the meters equally, the calorimeter is insensitive to ambient conditions. Repeatability of the instrument is of the order of 0.3 percent. Calibration is obtained by burning a pure sample of methane or a certified gas mixture of known calorific value.

More recent instruments operate on a ratio of gas and

air for combustion. The products of combustion are checked by an absorptive catalyst for excess oxygen (or fuel) and the above ratio is altered as appropriate. Variations in the ratio of sampling of the gas and air volumes are proportional to the change of calorific value.

Instruments operating on the above ratio principle use either a zirconium oxide sensor or a thermocouple to determine when the instrument is burning the gas/air mixture at the stoichiometric ratio. For the alkane series of hydrocarbons. The calorific value and above ratio have a linear relationship and the instrument is, normally, calibrated using pure methane. For this principle, the presence of unsaturated gas will increase the uncertainty of measurement. The overall uncertainty of measurements is, typically, 0.15 percent.

These instruments can be fitted with micro processors to process the data and control auto-calibrations as programmed.

ANNEX Q

(Clause 1.1)

SAFETY ASPECTS

Q-1 QUALITY OF GAS

Most gases that are distributed are non-corrosive. Quantities of dust or sand left from the construction phase may however be present. Though most gases are treated to have a very low hydrocarbon dew point, it does happen that liquid hydrocarbons find their way into the system. Means for draining filters should therefore be provided. This draining system may either of manual or automatic type. Gases should have a low water dew point to prevent hydrate formation. Water also increases the risk of corrosion.

Q-2 HAZARDOUS AREA CLASSIFICATION AND ELECTRICAL SAFETY

In a well designed and constructed gas terminal there shall be no leakage of gas. If any relief valves are present, their outlet shall be well above the installation or building. The only times when the occurrence of an explosive mixture can be expected is therefore during maintenance, and then only for short periods when a part of the installation is de-pressurized and taken apart. This would indicate that if a station is zoned at all, it shall be rated as a very low hazard (zone 2 for the European CEN 50014 standard). Still,

in practice stations are often zoned more hazardous (for example, CEN 50014 zone 1). The zoning of the station will have to be known before a proper design can be made.

Any electrical equipment associated with a meter installation shall be designed, constructed and installed in accordance with an appropriate standard. The hazardous area classification as given below, of the meter installation shall be determined by means of a full hazard assessment.

- a) *Zone 0*: An area in which an explosive gas/air mixture is continuously present or present for long periods.
- b) *Zone 1*: An area in which an explosive gas/air mixture is not likely to occur in normal operation.
- c) *Zone 2*: An area in which an explosive gas/air mixture is not likely to occur in normal operation and, if it occurs, it will exist only for a short time.

By implication, an area which is not classified as Zone 0, Zone 1 or Zone 2 is deemed to be non-hazardous or a safe area.

Even in safe area, account shall be taken of any constraints imposed by any adjacent hazardous area.

Where a meter is in a hazardous area, electrical equipment, for example, lighting and instrumentation shall be appropriately certified for safe use in the designated zone. If the required equipment is not certified or suitable for use in the designated area, it shall be fitted in a safe area or in a separate compartment having gas-tight walls and outside access only to a safe area.

Any electrical device and associated circuits, for example, a pulse transmitter, mounted in or on a meter shall be suitable for use in a Zone 2 hazardous area as a minimum requirement.

Metering installation may incorporate a variety of electrical supplies, both ac and dc. Power cables (220 V and above) for lighting and motors etc shall be separated by at least 0.3 m from instrument cables to minimize pick-up in instrument circuits.

Instrument and control cabling shall be screened cable with twisted conductors to be used to avoid pick-up. Cable armouring and screens shall be correctly earthed in accordance with the system and certificate requirements. All metering equipment's shall be immune to EMI/RFI interferences.

Cable screens and armour shall be insulated from the pipe work, especially where cathodic protection systems exist. Where intrinsically safe systems are employed, the cable parameter shall conform to the system certificate.

Intrinsically safe circuits shall not be intermixed with non-intrinsically safe circuits in the same multi-core cable.

Q-3 EARTHING

The whole of the electrical installation shall be earthed. Where sites have a cathodic protection, specialist advice may be required.

Q-4 LIGHTNING PROTECTION

If a nearby lightning strike could cause damage to

equipment and render it unsafe in a manner that is not obvious, the installation shall be protected against static discharge.

If there are reasonable grounds to believe that there is possibility of hidden, unsafe failures due to a lightning strike then suitable protection shall be provided in the form of either:

- a) A lightning barrier plus a certified protective device, or
- b) A lightning barrier suitable for Zone 2 hazardous area apparatus, as appropriate.

Q-5 NOISE

Most of the noise in a regulator station is generated by the gas travelling at high velocity through the regulator ports. The sound is transferred to the piping which in turn radiates it into the environment. The noise in a station therefore not only emanates from the regulator but also from the piping, in particular downstream. There are several ways to reduce the noise. Some regulators have special cages to break down the velocity more gradually. Some have different valve constructions with the same objective. All silent regulators are bigger and more expensive.

Heavier pipe walls and larger diameters generally help to reduce the noise as does external insulation, specifically of the downstream pipe work.

Q-6 STAND-BY INSTALLATION

With modern materials and proven operating principles present regulators and fittings are extremely safe and reliable. However, safety codes and regulations often demand additional safety devices. These codes have long traditions and vary considerably between countries. Before a station can be designed, all the relevant codes and standards valid for the particular site have to be known. The quality control and assurance for pressure vessels and piping also vary considerably among countries. Environmental concerns are mainly for the noise issuing from the station. The venting of gas to the atmosphere may also be restricted.

ANNEX R

(Clause N-1.3)

AREAS OF CONCERNS OF EXISTING TERMINALS AND CORRECTIVE ACTIONS

<i>Sl No.</i>	<i>Area of Concern</i>	<i>Proposed Corrective Action</i>
i)	Validation of orifice plates/turbine meter	1) Validation of orifice plates (inspection/dimension check as per ISO) to be done every 2 years. 2) Proving of turbine meters at working conditions every 2 years.
ii)	Meter installation improper	Station design as per ISO/AGA standards to mitigate the installation effects on the meter accuracy.
iii)	Improper meter selection	Meter type to be compatible with the gas quality.
iv)	Compositional analysis of natural gas	1) Installation of flow proportional auto sampling system/on-line GC for large consumers. 2) Spot sampling for medium and spot sampling at trunk line for small terminals with centralized lab GC.
v)	Flow control	1) Installation of the suitably sized volumetric remote flow control device in order to control the consumer for flow regulation for large consumers. 2) Local control with throttling valves for medium and small terminals.
vi)	Erratic power supply	1) Installation of properly designed UPS. 2) Installation of stand alone solar powered metering system.
vii)	Integrity of flow computer	1) Remote, on-line flow computation verification recommended using the real time measuring inputs in the SCADA system. 2) Sealing of custody transfer instrumentation system.
viii)	Condensate handling.	Provide automatic condensate handling and storage facility.
ix)	SCADA/Communication	Installation of reliable voice and data communication system for remote monitoring.

ANNEX S

(Informative)

BIBLIOGRAPHY

- | | |
|--|---|
| <p>OIML R 6 : 1989, General provisions for gas meters.</p> <p>OIML R 32 : 1989, Rotary piston gas meters and turbine gas meters.</p> <p>VIM:1984, International vocabulary of basic and general terms in metrology (BIPM, IEC, ISO, OIML).</p> <p>ANSI B46.1 American National Standards Institute.</p> <p>A.G.A. Engineering Technical Note M-96-2-3, Ultrasonic Flow Measurement for Natural Gas Applications, American Gas Association, 1515 Wilson Boulevard, Arlington, VA 22209.</p> <p>A.G.A. Transmission Measurement Committee Report</p> | <p>No.7, Measurement of Gas by Turbine Meters, American Gas Association, 1515 Wilson Boulevard, Arlington, VA 22209.</p> <p>A.G.A. Transmission Measurement Committee Report No.8, Compressibility Factors. Natural Gas and Other; Related Hydrocarbon Gases, American Gas Association, 1515 Wilson Boulevard, Arlington, V A 22209.</p> <p>NFPA 70, National Electrical Code, 1996 Edition, National Fire Protection Association, Battery March Park, Quincy, MA 02269.</p> <p>API Manual of Petroleum Measurement Standards</p> |
|--|---|

Chapter 21, September 1993, Flow Measurement
UsU Electronic Metering Systems, American
Petroleum Institute, 1220 L Street NW,
Washington, DC 20005.

ASTM Designation: E 1002-96, Standard Test Method
for Leaks Using Ultrasonics, American Society
for Testing and Materials, 100 Barr Harbor Drive,
West Conshohocken, PA 19428-2959, U.S.A.

Code of Federal Regulations, Title 49-Transportation,
Part 192 (49 CFR 192), Transportation of Natural
Gas and Other Gas by Pipeline: Minimum Federal
Safety Standards, U.S. Government Printing
Office, Washington, DC 20402.

GERG Technical Monograph 8 (1995), Present Status
and Future Research on Multi-path Ultrasonic Gas

Flow Meters, Christian Michelsen Research AS,
the GERG Project Group and Programme
Committee No. 2 — Transmission and Storage,
Groupe Européen De Recherches Gazieres.

OIML R 6 General provisions for gas volume meters,
1989 (E), International Recommendation,
Organization Internationale de Metrologie Legale,
Bureau International de Metrologie Legale, 11, rue
Turgot-75009 Paris-France.

OIML D 11 General requirements for electronic
measuring instruments, 1994 (E), International
Document, Organization Internationale de
Metrologie Legale, Bureau International de
Metrologie Legale, 11, rue Turgot-75009 Paris-
France.

Bureau of Indian Standards

BIS is a statutory institution established under the *Bureau of Indian Standards Act, 1986* to promote harmonious development of the activities of standardization, marking and quality certification of goods and attending to connected matters in the country.

Copyright

BIS has the copyright of all its publications. No part of these publications may be reproduced in any form without the prior permission in writing of BIS. This does not preclude the free use, in the course of implementing the standard, of necessary details, such as symbols and sizes, type or grade designations. Enquiries relating to copyright be addressed to the Director (Publications), BIS.

Review of Indian Standards

Amendments are issued to standards as the need arises on the basis of comments. Standards are also reviewed periodically; a standard along with amendments is reaffirmed when such review indicates that no changes are needed; if the review indicates that changes are needed, it is taken up for revision. Users of Indian Standards should ascertain that they are in possession of the latest amendments or edition by referring to the latest issue of 'BIS Catalogue' and 'Standards: Monthly Additions'.

This Indian Standard has been developed from Doc: No. PG 26 (1013).

Amendments Issued Since Publication

Amend No.	Date of Issue	Text Affected

BUREAU OF INDIAN STANDARDS

Headquarters:

Manak Bhavan, 9 Bahadur Shah Zafar Marg, New Delhi 110002
Telephones: 2323 0131, 2323 3375, 2323 9402 website : www.bis.org.in

Regional Offices: Telephones

Central	: Manak Bhavan, 9 Bahadur Shah Zafar Marg NEW DELHI 110002	{ 2323 7617 2323 3841
Eastern	: 1/14 C.I.T. Scheme VII M, V.I.P. Road, Kankurgachi KOLKATA 700054	{ 2337 8499, 2337 8561 2337 8626, 2337 9120
Northern	: SCO 335-336, Sector 34-A, CHANDIGARH 160022	{ 260 3843 260 9285
Southern	: C.I.T. Campus, IV Cross Road, CHENNAI 600113	{ 2254 1216, 2254 1442 2254 2519, 2254 2315
Western	: Manakalaya, E9 MIDC, Marol, Andheri (East) MUMBAI 400093	{ 2832 9295, 2832 7858 2832 7891, 2832 7892

Branches : AHMEDABAD. BANGALORE. BHOPAL. BHUBANESHWAR. COIMBATORE. FARIDABAD. GHAZIABAD. GUWAHATI. HYDERABAD. JAIPUR. KANPUR. LUCKNOW. NAGPUR. NALAGARH. PATNA. PUNE. RAJKOT. THIRUVANANTHAPURAM. VISAKHAPATNAM.